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Richard Volpe

An interview conducted by
Peter Asaro
with
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Richard Volpe: Do it at Loyola College in Baltimore, and then went to grad school at Carnegie Mellon, Pittsburgh.

Q: And what was your undergraduate degree?

Richard Volpe: Physics. And so when I was, oh, I guess, in junior year, I actually took a course that was a management course. We had this Jan-term that would offer courses, and this was called "Robots in the Workplace." And it was a management course, and I thought, "This sounds interesting." So I took that. And because it was a Jan-term, we went to class for extended periods every day of the week. And we did a lot of field trips to local facilities that had robots. And I got really interested. And we could write a term paper on anything that had to do with robots in the workplace in any way. So I wrote a paper that was actually more of a research, or a paper about research that was occurring at that time. And how that might impact the future of robotics. And so I basically didn't know it at the time, but I was doing a survey of all the graduate institutions that I might want to go to. And I saw a lot of interesting things that were happening at Carnegie-Mellon, so I said, "Ah, I want to go there for graduate school." So that's where I went.

Q: And in graduate school at Carnegie Mellon, you were still in Physics?

Richard Volpe: Ah, yes! So that was – so I applied to a bunch of graduate schools. My thesis advisor, my undergraduate thesis advisor said, "Oh, you should apply to a lot of graduate schools; that way, some of them will give you funding, and some of them will accept you all right, but not give you funding." And so I applied to Carnegie Mellon in both Physics and in Electrical Engineering. And I really didn't have enough of background in Electrical Engineering to get accepted into their program. But the Physics Department said, "Okay." So I ended up doing that. And it was the long way around the mountain because I ended up taking all the graduate courses in Physics, which were really not what I would end up using later. But it was an interesting route. And then after 18 months or so, I did my qualification exams. And at that point, I was looking for a thesis, thesis advisor. And I had worked in Takeo Kanade's lab the previous summer. So I immediately went back to him. And I think the funding situation was kind of precarious at the time. Just because of the ebb and flow of funding. And so he didn't really have something for me, and so I started knocking on doors all over the robotics institute at Carnegie Mellon, and I wasn't finding anything. So it was April, and I was probably a month away from finishing up my master's. Actually, I had my master's at that point, but finishing up the spring coursework. And so finally, then, I was talking to Steve Shafer who was working in Vision, and Steve said, "Ah, I think I have something for you." I had never thought about working in Computer Vision. And so I started working with Steve. And I liked it! But I still had my heart on manipulation. And I knew Pradeep Khosla, because Pradeep was just finishing his Ph.D. at that time, and his office was in the hall. And so after – I have to go back and check, but it was about six or nine months of working with Steve, Pradeep finished. And then he became a professor at CMU, and he said, "Well, if you want to switch and work on manipulation, I might have some funding for you." And the story is, as I remember it, was that the reason Pradeep had some funding was because Mark Raibert had just left Carnegie Mellon and went back to MIT. And I was just talking to Mark about this. And I don't know if this is exactly the right story, so we'd have to double-check with somebody like Takeo or Pradeep. And I understood it was like one year of an NSF grant that had to stay with Carnegie Mellon, and so when Mark left, they had this little chunk of money, and so Pradeep got it to give to me. And so then I had coverage for a year, and then I felt bad, because I had to go talk to Steve Shafer and say, "Steve, you know, I'm more interested in manipulation." Steve was really good about it, and so then I switched over. And then Pradeep basically said, you know, "We have to find funding for next year right away." And that was an interesting situation because at that time, basically, I was a physics student working for a EE advisor in the computer science department. And so I was trying to make everybody happy. And also trying to get funding, because you couldn't get funding through the main channels. You know? Pradeep could get funding for EE students but not for a Physics student. So we applied – or I applied around for a bunch of fellowships, and luckily secured one from the Air Force. And it was like the first year of – that they were giving out these fellowships, and after I got that one, everybody was going, "How did you get this? Where did you get this?" And so, and it was a very popular program after that. I'm not sure if that program's still in existence, but it did me well. And so then I worked on manipulation for three years, and then Pradeep knew some folks out here at JPL, and I always had an interest in space. And so once I heard that they were interested in me, and they were doing work that was interesting to me, I accepted the offer and came out here. And I've been here now for 20 years. So.

Q: What years were you at CMU?

Richard Volpe: Oh, 1990 to – no, no, no. I left in 1990. It was 1984 to 1990.

Q: And so how did you get so interested in manipulation?

Richard Volpe: So for me, that was always robotics. So it's interesting to me, how manipulation is now becoming very popular, again, because the robot arm, to me, was, you know, there's always the Hollywood version of a robot, which is always the humanoid. But I think if you go back to the beginnings of robotics, it was always the pick and place robot arm in the factory. And so having a manipulator that can perform better was always more interesting to me. And then there's obviously the other side, which is sensing, perception, the autonomy aspects. But I just was kind of attracted to the manipulation side of things. And I heard a story one time – who told me this? Maybe it was Steve Shafer who used to quip this, that, you know, it was always the people who didn't have good eyesight who were attracted to the computer vision, and all these, the clumsy people who were attracted to manipulation, and so on and so forth. So I don't know if that's true or not, but <laughs> you can make your own judgment.

Q: So do you call yourself cool?

Richard Volpe: Yeah. Maybe, maybe not.

Q: So what were some of the problems that you started working on in manipulation as a graduate student?

Richard Volpe: Well, Pradeep and I talked about that early on. And really, force control was a hot topic at the time. And there were several different approaches to force control at the time. And there was this kind of bifurcation. There were many different approaches, but there were maybe two schools of thought in explicit force control and impedance control. And so, not only did I want to more fully learn about what those were, but in the course of doing that, I felt like I was able to merge them into one framework. And so that was, I think, one of the contributions of my thesis.

Q: And how did that work with the Physics doctorate?

Richard Volpe: Ah, well, so that was an interesting story in and of itself, because the Physics Department was fairly okay with it, as long as you were able to find your own funding, because they didn't have it for me. And then also, I found out on the day of graduation when I got my diploma, it said, "Applied Physics" on it – it didn't say "Physics!" And so, and I was like, "Oh, I didn't know that I was getting an Applied Physics degree, but who cares at this point?" You know, and so I asked somebody about it, or maybe I figured it out. And back on my application to the department, they had, I think three boxes. And one was "Theoretical Physics," one was "Experimental Physics," and one was "Applied Physics." And I had checked the "Applied Physics," because that best described what I wanted to do. But they didn't give out separate diplomas for "Experimental" and "Theoretical," but they did give out a different diploma for "Applied Physics." So that makes sense. And so I had a couple professors from the department who were – had a more experimental bent to them. And actually, also, it goes back to when I first interviewed at the school. There was a student – I'm trying to remember his name. I think it was Michael Fuhrman, and he was working with Takeo Kanade on, I think, vision problems. And he was a Physics student. And so when I met him, I knew that there was a possibility of being a Physics student and working in Robotics. And so it may be as simple as the department decided, "We need to have one student who's doing this, and this guy's graduating. We need somebody to fill that slot." But I never heard that. So anyway, I just knew that there was a way to go through the program that way. So, I fell on that route.

Q: How is it to work with Pradeep?

Richard Volpe: Oh, Pradeep and I got along great! So what can I say? I was his first graduate student, and so it was kind of funny, because other students came along, and some thought that he was hard-driving, or harder to work with. And I never had any problem. So he and I got along great. And the fact that I was his first student, I think, even made it better. So.

Q: And what about Takeo?

Richard Volpe: Takeo? Takeo was on my thesis committee and like I mentioned, I worked kind of with Takeo that first summer. But actually, I was working for a visiting – can't remember the guy's name, but he was a visiting person from one of the Japanese companies, and so I was working with him really. So I never really worked directly with Takeo. But we did have – maybe it was that first summer, or the first year, we had reading sessions in Takeo's office. And I remember, we would always be odd times like, you know, Saturday afternoon or Sunday morning, or something that I thought was kind of outrageous, but it was completely normal to him. So and we had a great time! Because it was the only time, I think, where he felt he had time to sit down and actually think about a problem. And so we were – I'm trying to remember which papers we were reading, but they were fairly dense. So I would read the paper and make sure I understood it completely, and then I would actually try and present it to he, and Pradeep and others. And that was a good learning experience. You know, especially given that they were only getting exposure to it during that time slot once a week. They asked some pretty probing questions. So I think that especially since Takeo's main interest – although he has had these forays into manipulation, his main interest, historically has been in vision. So the fact that he still had this desire and interest in manipulation was commendable.

Q: And was this just you and your committee, or were other students involved in the reading group?

Richard Volpe: That reading group was – it really wasn't a reading group. It was me reading papers and presenting them to them. And I think it was just Pradeep and Takeo and maybe somebody else that I'm forgetting, but it was a small group, and we'd do it like once a week, or maybe it was less often. Maybe it was once every several weeks. Now there was a real – Matt Mason used to run a full-fledged reading group. And that was maybe a year or two later. And that was interesting as well. Matt's primary interest is manipulation and we had a number of graduate students who were in. So as I mentioned, I was kind of working in computer science, but I was also working in really a vision lab. I was surrounded by vision researchers. So I got a lot of exposure to computer vision, and learned a lot in that way. But I wasn't interacting as much with manipulation folks. And so Matt's reading groups provided that – provided a venue in which we could do that.

Q: And who were some of the people that you worked with most closely during grad school?

Richard Volpe: Let's see, well, obviously, Pradeep. And there was a guy named Dave Stewart, who I still keep in touch with, but haven't talked to in a while. And Dave was developing a new operating system called Chimera. And so he and I worked together very closely. He needed me to use his software and find his bugs, and I needed him to get anything working. So – and we were good friends also. We would go out and have a beer together and such. So and that worked well. And then Nick Papanikolopoulos came in about, maybe – vaguely in my mind, I'd have to double-check the dates and such, but I remember Dave being there first and then Nick showing up later. And so – and Nick was kind of in the same boat. He needed my stuff in order to get his stuff. Because he was mainly interested in the vision problem, but he needed the arm to be working. And so he used all my software, and I was very happy to not to have to deal with that part of the problem. Let's see. Another very close friend didn't work with directly, but sat like within arm's reach of, 'cause the offices were very crowded <laughs>, was John Krumm, who's now at Microsoft. And so John was one of Steve Shafer's students. And so, I actually learned a lot just by seeing what John was working on a day-to-day basis. And then Rich Wallace was a member of the office for a while. And then the fourth desk – in this very small office – was occupied by a couple of different visiting researchers. One was Masa Okutomi, who is now – well, Masa, forgive me, I think you're at either at Tokyo Ins – no, he's not at – he's at – yeah, Tokyo Institute of Technology. That's where he is. And Yoshi Kuno. And Yoshi is I think at Osaka University, if I'm remembering correctly. So they were also, obviously, vision researchers. And so again, I was learning. And then Gunhee Kim was also another visitor, and he's back in Korea now. In fact, I just saw him for the first time when I went to a conference in Korea. So it's been a while.

Q: So what kinds of platform were you working – or platforms were you working with?

Richard Volpe: The primary platform was the DDArm-2, or DirectDriveArm-2, which was built by – it was really built by – let me see if I can remember the names here. Well, Pradeep was the first user. And Don Schmitz was the Mechanical Engineer, who I believed designed all of the parts. And Mark – and I'm forgetting Mark's last name. He's still at Carnegie Mellon, I believe, was a machinist at the time. And I think he fab-ed quite a few of the parts, if not all of them. And so the arm was obviously number two, from the name. The first one was, I think, the creation of Takeo and company, and was a big red monster that was kind of mounted from this some kind of steel superstructure. But the DirectDriveArm-2 was put on a base, and so it had a SCARA configuration. And so I don't know the relationship between the SCARA configured arms that came out of Adept, but there seemed to be some cause and effect between the design of the DirectDriveArm-2 and the subsequent Adept design. And so, but the interesting thing about the DirectDriveArm was that it was very fast. And it didn't have brakes. <laughs> So it stopped either 'cause it hit a hard stop, or because, you know, even if power was turned off, it was almost frictionless. And so when you're doing controlled experiments on this system, and you're algorithm goes unstable, you get to find out in a very spectacular fashion. So that was kind of fun.

Q: Well, there's some interesting crashes, like –

Richard Volpe: Luckily, no. We – nothing – we obviously, I was – I mentioned that we were doing force control, and so there was a force sensor on the end, and the force sensor had a probe on the end of it for touching things. And I think we bent it a couple times, and but, I don't remember actually breaking the arm, luckily. Oh, I know what we would do. A lot of times the cables, you know, you're a poor graduate student, and I think they used to charge, I don't know, a hundred dollars for the cable coming out of the force sensor. And we'd have this – run the cable back and make sure there were proper service loops around all the joints, and bring it back to the processing box that was mounted near the base. And we probably ripped up a couple of those cables. And you know, every time I broke a cable, as a poor graduate student, I'd say, "Oh, my god! A hundred dollars!" <laughs> We should have had a box of cables, but it kept me from breaking too many of them, I suppose. <laughs>

Q: And did your exposure to the computer vision folks have any influence on your research?

Richard Volpe: Not really. No. No, I just got to learn about it. In fact, you were mentioning earlier that you interviewed Larry Matthies, and Larry was also in that hallway at the time. He was back at Carnegie Mellon. And so I used to see Larry's work on stereo vision at the time. And there was a lot of people who were working on at the NavLab who were doing automated driving, and so I was learning a little bit about that. But just by looking over people's shoulders, that's all.

Q: And so after Carnegie Mellon, you got here.

Richard Volpe: Yeah!

Q: Coming here.

Richard Volpe: So JPL at the time was primarily working on manipulation. Dual-arm, force reflecting, tele-operation. It was a lot of mobility research as well. There was the Robby system, which had a manipulator on it, which was a large-scale prototype for a Mars rover. But I would say the bulk of the work was in manipulation for the first couple of years. And then with the successes of the mobile robotics, kind of the pendulum swung, and so we got into the business of putting rovers on Mars. And those rovers, at first, didn't have manipulators on them. And so it's only been more recently that I think the community as a whole, and we also are getting back to where, I think, maybe the manipulation is going to become dominant over mobility. But there was this whole period where mobility was dominant. And it's interesting, I only got into the mobility side of things because we were going to build this rover, which got named Rocky-7, and I was originally placed on my project to provide manipulation capability for the rover. And so over the course of that project, I ended up being the lead engineer for the whole rover. And task manager. And then we got into a lot of issues with software, and then I ended up leading this whole software effort, which we called CLARAty. And then from that, that had such a need to bring so many people together that I started to do more programmatic work than technical work. And so then I moved into the Program Office here at JPL. So it was kind of one thing flowed into another. So that's kind of the short synopsis.

Q: So what were some of the interesting questions that you had dealt with while you were here, some of your earlier work here, before you got into the programmatic direction?

Richard Volpe: Well, it was a lot of system engineering issues. So we were – when we put together Rocky-7, the real question was, "How much can we cram into this little robot?" Because there's always this constraint for mass power and volume on flight projects. And we were trying to do a research project that would be relevant to the flight project. And so what we were kind of handed is that, well, you can go back even – takes that back – and describe what I did before. There had been a NASA research project, or set of projects that I hadn't worked on, which had Ambler at Carnegie Mellon and Robby here. And they were both very large robots. And I think the reason they were large was there was a constraint put on them early on that they'd be able to climb over a meter obstacle, or cross a meter ditch, or something like that. And so at one point, everybody said, "These things are too large, you're not going to go as – we're not going to get them to Mars." And there was a whole other school of thought that was coming into being through Rod Brooks at MIT, and a lot of people here, were working on small behavior-based robots that were much more lightweight and compact. And so that school of thought at the time ended up winning the day in order to get to Mars first. But as we see from the MSL vehicle, we've kind of – what's old is new again – so we've gone right back to this huge robot that's going to be on Mars. At the point when I worked on Rocky-7, there was this issue of… Sojourner was on its way to Mars, and everybody's saying, "Well, it's nice, but we don't see it as being capable enough to, for instance, be its own lander." Sojourner was very reliant on a lander that it could talk to in order – for just things like carrying enough power, carrying the comm-system. You know, things like that. So the challenge with Rocky-7 given to us was can you make a robot that's kind of self-contained and can be its own lander? And do that. And so we set the challenge to make the robot about the same size as Sojourner, but give it more capability. And so, for instance, it had manipulation onboard, which Sojourner didn't have. It had a mast onboard, which was actually a deployable manipulator so that it could raise cameras up and look around, which Sojourner didn't have. It had stereo vision, front and back, which Sojourner didn't have. So we needed a more capable processor. But in order to have a more capable processor, we needed to have more power. So we had to carry more batteries, and so, you know, but you have to cram it all into a small box. So that was – it was really almost like building a small spacecraft. Obviously, a prototype. But it had all of the system level issues that we had to deal with. So I went from just being concerned with manipulation and manipulation algorithms to really getting into the system engineering of the whole vehicle and the tradeoffs that would occur as you go through that engineering exercise. And so I think we were very successful. I think that the capabilities that we put into that system influenced the design of the MER vehicles. They ended up being larger, and that's more of a function of caring more science payload. It turns out that each of the rovers we put up there usually are about ten times as large as the science payload that they carry. So if you – as the scientists come along, they keep wanting to put more instruments on Mars, and so the rovers get bigger. So that's kind of the way it works. So I think that's more of the reason why MER was a little bit bigger. But a lot of the design tradeoffs and the kind of layout of the rover was influenced by the work that we did.

Q: And just to give people perspective, how large is large, and how small is small in this case?

Richard Volpe: Oh, well, Sojourner was about the size of a small microwave oven, I guess. And MER was about the size of this table. And MSL is about the size of a small car. So, yeah.

Q: Thanks. It's hard to tell, we've seen some of them, and they can be the size of the room. But –

Richard Volpe: Oh, yeah, yeah. I don't know if you – this is kind of outside of the interview, but I don't – MSL is actually about to be buttoned up for shipment to the Cape, but it's here still. If you're interested.

Q: We got to see the mobility test.

Richard Volpe: Oh, you did get to see something?

Q: It didn't move while we were there.

Richard Volpe: Okay, but we got to see it.

Q: Immobile mobility.

Richard Volpe: Okay, well, you got to see it, so okay. You know, that's all I can – I was going to say, if you haven't seen it, you should see it before it goes, because the next time you'll see it, it'll be on Mars.

Q: And it's never coming back.

Richard Volpe: And it's never coming back. And you're not going to really get to see it, because it has the only cameras, and so you'll just see the top deck, and there's no mirrors on Mars that it can take a self-portrait, kind of thing. Too bad.

Q: So what did robotics look like at JPL when you got here, and how has it changed over the years?

Richard Volpe: Oh, that's a good question. So a lot of that has to do with – it has changed. And a lot of that has to do with the funding and the way funding – the way NASA has changed. So when I first came here, NASA had an organization called Code R, which provided blocks of money to the NASA centers. Actually, there was an organization called TRIWG, which stood for the Telerobotics Inter-Center Working Group, and I didn't participate in TRIWG meetings, because I was a junior person here. But several people, including the person who was the section manager here at the time, would go to those meetings and they would negotiate with the other NASA centers in order to decide what kind of work's going to get done within NASA robotics? And who's going to do it? And at what levels? So on and so forth. And then also there were block grants of funding that went out to several universities, and I think MIT was a recipient of one of those. And so they would work on basic research. And so there was a – so that funding, both inside of NASA and outside of NASA was more basic research in flavor. And in fact, there was a lot of people who talked about something called a TRL gap. So TRL stands for Technology Readiness Level. And there's this system of TRLs that go from one to nine, where one is as you just thought of it yesterday, and nine is it's been in space. And so one through three was considered research, and seven through nine was considered space flight, or ready for space flight. And so there's this middle band where you're really maturing the technology and it goes four through six. And at that time, because there was a lot of research that was being done through Code R and low TRLs, there was considered to be this gap, TRL gap that existed and it was hard to get new technology to flow into flight projects. And so that's why, for instance, that Sojourner was only a flight experiment on pathfinder, it was not part of the pathfinder mission, because they – the flight projects were very hesitant to adopt such a radical new thing that hadn't been put on Mars before. Even though, I mean, a lot of people want to do it, but when it comes down to you know, am I gonna sign on the dotted line? And my mission's gotta succeed or fail based on this technology. And they say, "Well, I don't know if that technology's really ready." So what was created was, especially since we were doing more and more Mars missions, that was a new program that was created called the Mars Technology Program. And that was really geared towards addressing this mid-TRL funding to mature technology. And Samad Hayati was the program manager of that here at JPL for a number of years. And I had worked for Samad in the past, in fact, Samad was the first person I worked for when I came to JPL. So I continued to work for him as getting funding from the program, but then eventually I moved through the program itself to work on that and help promote this idea of flowing technology in. But what's interesting, what's unfortunate, I guess, is that from my perspective what happened first is that there was the Mars Technology Program covering the mid-TRLs, and there was still the Code R program which was providing low TRL funding. But slowly the low TRL funding started to diminish and disappear, and then ESMD came along, and I don't know if you're familiar with ESMD. So ESMD is a NASA program, actually a NASA directorate that funded everything to do with the Constellation Program, and the desire of NASA to go back to the moon. And so there was a research program underneath of that.) It was all mid-TRL-related. It was, "Let's take existing technology, mature it, and then get it on the moon. And so when ESMD was created, Code R was killed. And so what you had over the course of ten years or so, it was a transition from everything was being funded at low-TRL, and there was no mid-TRL work. To a different situation where there was all this mid-TRL work and no low-TRL. So we were just eating the seed corn, I feel. So the basic research that we were doing here was funded somewhat in drib and drabs, I think, from NASA, but we were also getting non-asset funding from various DOD sponsors. And we continue to do that. So that's the situation there. I've already forgotten the question.

Q: The question was what it was like when you got here in robotics and how it changed. But in terms of funding, like how much of the funding actually comes from within NASA; what other sources, and how much comes from those other sources for the robotics work?

Richard Volpe: So right now – well, the other thing that has changed is in the past, when I first came here, most of the funding that we received was from research sponsors, and now we do about half flight work, so we have about half the people in the robotic section of JPL who are working on flight projects. Right now that's predominantly MSL. We also have people who continue to do operations for MER, and we also have some people who are doing pre-project work for various other things. So we've gotten this new balance where we're doing half flight and half research, and that's really helpful, because the flight experience helps drive the research, and flight people sometimes come off the flight projects and come back into research, and then they sometimes have more grounded ideas. And it actually provides a very nice balance for the staff here.

Q: You mentioned Rocky as the first project you worked on. Did Rocky ever go to space?

Richard Volpe: No. So it wasn't the first project I worked on actually. Yeah, I worked on a manipulation project. We were working on this project for doing inspection of the space station, because even back then – this was 15, 20 years ago – there was a recognition that the space station will suffer degradation over time, and so it's going to need some inspection capability. The latest ideas for that have been to have free flyers that go outside, but at the time we were looking at sensor platforms that are carried by the manipulation systems on the space station to be able to go out and inspect the external parts of the space station. But, anyway, that was what I first worked on, and then I started working on manipulation for Rocky 7, so it was called Rocky 7. So Rocky-s one through four were developed by a group that was actually in a separate organization at JPL at the time, led by Dave Miller, who is now I believe at the University of Oklahoma if I remember. And so the Rocky 4 vehicle was the predecessor to Sojourner, and so five and six were drawing board concepts and never got built, and then we built seven, which was built. So we were testing the first version of Rocky 7 just as Sojourner was landing on Mars back in '97 I guess that was.

Q: If Rocky 7 didn't go, how were the things you learned there used?

Richard Volpe: Well, that's what I was trying to say before, is that I think that the design exercise there led to what was used on MER, so the idea of having stereo cameras front and back, stereo cameras on a mast, the navigation algorithms that we were developing and testing, having a manipulator on one end of the vehicle, just the operational concepts. In fact we developed a new operator interface, which through many iterations eventually became the flight operator interface and is used to this day in a different organization here at JPL, and so all those things kind of influenced the subsequent missions.

Q: Was MER the next one that you went to?

Richard Volpe: No. So early in the days of MER I had a chance to work on the software team for the rover, and I also had a chance to start working on this new software system, which we called CLARAty, and then also doing this more programmatic work, and so I kind of chose that instead of going on to the flight project. And, yeah, anyway.

Q: Could you tell us a little bit about the organization from your perspective as program manager?

Richard Volpe: Yeah, so that was a fun job actually, and it was at that time also that I had had a few visits to DARPA and was thinking about becoming a program manager at DARPA. And there was a change of administration going on and the funding situation was very uncertain, and it looked like that if I went there, there might not be a program or money to establish a program, and the Mars technology program was offering a small program here, and so I decided to stay. And so we had a dozen or so research tasks that were all working on developing new technology for Mars rovers, and we were also developing this new software system, which I enjoyed participating in, and so we were moving the state of the art forward for the Mars rovers, and some of the technology you can explicitly trace into its implementation on MER and MSL, so it was very fruitful.

Q: What were some of the challenges with the new rover?

Richard Volpe: Well, it's always trying to get it to be more capable. So when you put a new system on the planet the project itself, they have very stringent requirements, which often don't involve much autonomy, because they figure if we can just get there and keep the system alive on a different planet that's good enough. But MER at least had a more capable processor. Even though it was only a 20-megahertz processor it was still reprogrammable and we could try and get new algorithms up to the vehicle. So after the system was alive on Mars for many years we were able to get these new algorithms that were originally being developed for implementation on MSL. We were able to get them implemented on MER, and so that was one pathway for the infusion of the technology. So, for instance, we had target tracking, and we were even trying to get infusion not just from JPL or the NASA community, but we were working with Carnegie Mellon folks, and so Carnegie Mellon's path planner ended up getting integrated into MER rovers through this pathway that we developed.

Q: Who were some of the people that you were working with?

Richard Volpe: Well, here Issa Nesnas was working on the software system and was a key person, but then externally Tony Stentz was one of the task managers. We were working with Steve Dubowsky at MIT. Going back to CMU it was Al Kelly. You're catching me off-guard. I have to think about that a little.

Q: More institutionally how does the role of JPL within NASA Robotics relate to, say, NASA Ames or the Johnson Space Center, where they were also doing robotics work?

Richard Volpe: So do you imply from your question that there is kind of an agreed to role for each center, or are you just saying...

Q: Are they collaborating? Are they competing with one another? Are they just separate?

Richard Volpe: So under this research program that I was mentioning before we were collaborating with NASA Ames quite a bit, and they were contributing to the software infrastructure, and it was very much a collaborative effort for that particular project. At the time there wasn't as much going on with Johnson, but we had interacted with Johnson prior. The person to ask more about that is – Paul Backes had a lot of interactions with Johnson back then. And then more recently when ESMD got started that's when – Brian Wilcox has been primary interaction with Rob Ambrose and company at Johnson. So I'd say it kind of ebbs and flows, the interactions, and it has to do more with the type of work. Johnson in particular has always had more of a – their reason to be is for the manned space program, and JPL's reason to be is for the unmanned space program, so then you look for overlaps, and those overlaps sometimes come and go. Ames has concentrated more on software and autonomy, and so during the years when I was doing program management work we were interacting more with Ames. Ames has since been interacting more with the ESMD crowd, and so I would say, outside of the athlete work that Brian maybe told you about, the number of people who have been interacting with the Ames folks has been smaller in recent years, but that's just an ebb and flow of the programmatic structure. It has nothing to do, say, about what we'll be tomorrow.

Q: So when you were talking about being director, that's when you were being director of the autonomous systems division or...

Richard Volpe: No.

Q: No. Can you tell us a little bit about that?

Richard Volpe: I'm not sure what you're referring to.

Q: I just read your online thing, and it said you were a director of the autonomous systems division...

Richard Volpe: Director?

Q: ...dealing with 80 people...

Richard Volpe: Okay. I'm not...

Q: ...and did research in space flight employment on roving, digging, ballooning and all kinds of things that had to do with... <laughs>

Richard Volpe: Okay. So not to correct you, but the title "director" isn't used here, so I'm section manager, yeah. Yeah. Yeah.

Q: I think I just copied it from the online...

Richard Volpe: Oh, well, if it's there then I'll have to get the...

Q: Maybe I copied it wrong.

Richard Volpe: Yeah, I don't know. Anyway, I am the section manager of the mobility and robotic system section, and the mobility and robotic system section is in something that's called the autonomous systems division. And so my boss wouldn't like it if I said that I was in charge of the whole division, and that's what I heard you say. <laughs> So, anyway, the mobility and robotic system section is called mobility and robotic systems because mobility is very important, and most of what we do is robots for mobility capability, at least up until the present. And that goes back to this whole issue about the ebb and flow between mobility into manipulation. So we've been looking at different forms of mobility, not just surface mobility and not just the surface of barren surfaces like the surface of Mars, but we've been looking at both wheeled and limbed vehicles for being able to traverse a variety of hard surfaces as well as autonomy that would provide capability to go across liquid surfaces. We've been working on DOD projects in that regard. We've been looking at aerial platforms, usually lighter than air blimps and balloons, for mobility. We've even looked at subsurface mobility, trying to have melt probes that would go through the ice and be able to steer themselves, so on and so forth, anything that you can imagine that would be of utility to exploration of the planets or act as a way in which we could stretch our concepts of autonomy and trying to improve things there as well. So the section is very diverse. We now have eight different groups, and we work on everything from mechanisms through software through system design, and we work for a whole host of different sponsors. And I mentioned already that we're doing half flight and half research, but even on research we're working for NASA as well as NASA sponsors, so...

Q: Have you personally gotten back to any manipulation research?

Richard Volpe: Mmm, no, not as much as I would like. I mean, I sit in reviews at this stage of the game.

Q: Also on the same Web page it said something about you being on the Phoenix mission robotic arm team.

Richard Volpe: Yes, yes. So that was in 2008, and actually before that I knew that it was going to happen. So a member of the section, Bob Bonitz, he's been the lead in a number of manipulation efforts, including a similar lander that was going to land in 1999, I think it was. It was the Mars polar lander, and it crashed, and so that was a big disappointment for him. And then he went off and worked on the manipulation team for MER, and then he was the lead for manipulation for Phoenix. And it was only two of them that were working on – now, they were overseeing the actual construction of the arm, which was being done by an external contractor, but he and Matt Robinson were the two people in charge of that particular subsystem. And so they knew that two people couldn't possibly handle the operations once we got to operations on the surface, so actually the science lead, who was kind of his organizational boss on the mission, came to me as a section manager and said "We need more of your people to work operations." And I knew that we didn't have all those people, and I also knew that I was interested in doing it, and it's very unusual for a section manager to go off and work operations, and so I talked to my boss about it and I said "Well, what do you think?" And one of the things that made it feasible was that we knew by design that the spacecraft was only going to be on the surface of Mars for three months because it landed above the Arctic Circle, the planets are going to move, it's going to end up getting dark, and it was a solar-powered spacecraft and it's going to die and get frozen. So I said "How about if I take a leave of absence from my section management job for three months and go do this?" And since, as I mentioned before, I had given up an opportunity to work on MER earlier, this was kind of a chance to go work on a flight mission and maybe not in the capacity of writing the software but at least doing operations. So that's the way we did it, and it required not just the three months of the spacecraft being on the surface, but there was also the six months ahead of time where we were doing numerous practice trials, and then it was also compounded by the fact that it was all being run in Arizona, so we had to move to Tucson, and it added an interesting twist to it, because you're living away from home, and living in Tucson in the summertime it was kind of hot. And working Mars time is very strange, because you're – I don't know if you've heard anything about this. Okay. He's shaking. Yeah, I'll explain it anyway, so yeah. It's 24 hours and 39 minutes I think it is every day, and so every 40 minutes every day you're shifting ahead, and actually the way it works is because everything in operations gets synced to when the data comes, because basically your day starts when the new data comes in from the previous day, so you find out what happened, and then you spend about 14 hours building sequences and uploading them to the spacecraft so that it can do new actions. And so when that orbiter pass occurs it bounces around. There's jitter just because of when they do their relays, and so you might have a 22-hour day, a 22-hour day and then a 26-hour days, and it jumps around like that, and slowly you move forward. And so you start off going to work at three o'clock in the afternoon, and then two weeks later you're going to work at 8 PM, and two weeks after that you're going to work at three in the morning, and it wreaks havoc on your body clock, and so you're just struggling to work a 14-hour day, get some exercise in, go to bed, try and get your body to deal with the changing clock. And they're about to do this all over again with MSL, because it'll be the same thing. So if Mars didn't rotate at approximately the same rate as Earth, if it took a lot longer or a lot less there'd be no attempt to try to do this, but because it does it actually maximizes the utility of the spacecraft on the surface, and so it's the best thing for mission return, but it's really difficult for the operators.

Q: How many people were you working with as an operator?

Richard Volpe: We had a small team. It was five people, and it was cost-constrained, and so we had a five-person team, which – I'd have three people – in the beginning for the first month, the whole month of June – so this was almost exactly, what, three years ago, because it was June 2008. Yeah. And so that first month we worked seven hours a day – I mean, excuse me, seven days a week, 16 hours a day for the entire month. And then after that we broke it down to three people – usually you have four people on and then one person gets off on each day, and so we ended up working – and so you'd have a four-day shift and then two days off, and so the days off is actually like – it was almost exactly 48 hours off, and so your 48 hours off might start anytime during the day. It might start at 3 AM, and so you couldn't catch a flight back to LA until obviously 8 AM, so you've already lost five of your hours, and <laughs> it was interesting.

Q: What kind of operations were you controlling?

Richard Volpe: Basically we were building the sequences for the manipulator, and we were interfacing with the science team. So the scientists would come to us and they would say "We want to dig here" or "We want to point the camera another location," and there was a camera on the arm. And then also we had to do this dance where the mast cameras – they would want to image train over here, so you'd have to move the arm over to here, make sure you're doing all these operations over here, and then when they want to look over here you would move the arm over here and make sure you do – so you're trying to coordinate a full schedule. And something tells me you could've probably built a software system that could automate all that, but it was never in the budget for the whole mission, and so it was intensive negotiations amongst a number of different science teams, and we were kind of the focal point because we were one of the main instruments. And then not only did we have to dig but we had to deliver the samples, and so the only way that all the sampling instruments were going to get their samples in order to meet the mission success was with the dirt that we were delivering, so we were dirt diggers, ditch diggers, so it was fun.

Q: Were there any exciting, surprising or annoying moments that you remember from taking part in this?

Richard Volpe: The most surprising moment was when we thought we had dumped dirt successfully on one of the instruments, and we got the pictures back, and the dirt had not come out of the scoop. And that led to a whole actually scientific discovery about the way that – the dirt had some water in it, ice, and because we had left – there was a desire to break the actions down into a series of steps and then try and image those steps in order to be able to document as well as debug. And so one of the steps was "Oh, wouldn't it be nice before we dumped the dirt to position the scoop so that the sun can shine into the scoop?" And you have to figure out where the sun's going to be during that time of day and make sure you're not casting shadows, and it can be a little bit complicated, and then image that and then dump the dirt. But in the process of doing that there were pauses and time passes, and so just that little bit of sunlight, even though it was very cold on Mars, was enough to cause local melting with subsequent local freezing, which caused the dirt to stick into the scoop. And so when we turned the scoop over it didn't come out, and so we got the pictures back. There was no dirt, and we were like "Where's the dirt?" <laughs> So it was a little bit of a surprise and…

Q: But you found water?

Richard Volpe: Well, yes, so we found – I mean, we saw ice in lots of different ways. It was fun.

Q: Outside of NASA and JPL, have there been other important collaborations that you've participated in?

Richard Volpe: Not that I can think of. Are you aware of something that I'm not thinking of?

Q: Are there any particular people you've worked with from other institutions or...

Richard Volpe: No. Can't think of one right now.

Q: I also saw that you were a member of JPL's science and technology management committee.

Richard Volpe: Yes.

Q: What was that like?

Richard Volpe: It's ongoing. So that's partly because I'm in charge of a section that does a lot of technology development because of the programmatic experience I have we have a committee here that's comprised of a number of people like myself who are division technologists from across the laboratory. And the purpose of that committee is to come up with strategies for improving the technical infrastructure, and also we have internal IRAD money, and so that committee is in charge of the process to distribute that money.

Q: What are some of the processes of weighing that you have to go through in terms of making decisions of where things are going or what's the next direction?

Richard Volpe: Well, I think that we're actually at the very beginning of that cycle, and that cycle is driven by the Decadal Surveys that are done for NASA by the National Academy of Sciences. So NASA asks the academy "What should we do for the next decade?" And the one for space exploration for the science mission directorate just came out in April I believe it was and set-up the objectives for the next decade. And luckily one of the top objectives was sample return from Mars, but now we're trying to figure out how to potentially do that, and so there's a lot of discussions about collaboration with the Europeans to help create a mission potentially in 2018 to start that process. So that's an example of the science community tells NASA what's important, and then NASA looks for the NASA centers to try and develop the technology to make those missions happen.

<break in recording>

Q: We're back up.

Richard Volpe: So I think your question was "Is there a cross-purpose between what people want to work on technically and what the scientists want?" And I would say sometimes, but the science community is broad, and there's a lot of different scientists who have differing points of view. And so an example of that that one might point to is an issue that we kind of broadly classify as autonomous science, although most scientists would probably chafe at that term. And it's really maybe more properly described as autonomous science data processing. And so there are some scientists who want their instrument in the field on Mars or someplace else, and they want to get back the raw bits, and they don't want any processing beyond the raw bits. They would probably prefer to have the analog signals if they could have that instead.

<off-topic conversation>

<break in recording>

Richard Volpe: So the autonomous science data processing. So there's some scientists who would like to just get the raw data back, but the problem with that is if you don't compress it in some fashion then you only get limited data back. And so especially with newer science instruments where the data quantities are very large then some kind of way to compress the data is attractive to those scientists, and that could be as simple as just a compression algorithm like image compression, but it could be something much more intelligent where you're actually filtering sets of data and saying "Oh, well, this set of data doesn't have anything interesting, and so we'll just throw that one away or we'll put it in a buffer and save it or we'll send down a reduced-resolution version of it and let you decide." There's all different ways, and so I think that scientists in general are very open to these new techniques. Now, as you go across the spectrum from raw data to compressed data to processed data and you keep going eventually you can say "Well, the spacecraft's going to be so smart that it will just send back the journal paper," and, no, they don't want that. The scientists don't want that, <laughs> so there is some point at which they will draw the line, and we're not close to that yet, so we're not worried about that.

Q: What do you think are the biggest technological challenges facing robotics over the next few years?

Richard Volpe: Well, I know what's popular or what's being funded these days, but sensing I think is maybe just a little bit ahead of sensor processing, interpretation of data, and so I think the interpretation is probably one of the hot topics. But if we got to the point where you could put a camera and other sensors into a room and completely understand the situation you still have the flipside of the problem, which is, okay, now you're a surveillance system or whatever you want to call it, but you aren't interacting with that environment, and so it goes back to manipulation, which is my favorite. Now, I think as long as you have an environment that is structured for humans then you're going to have to have robots that can deal with that environment that's structured for humans. Otherwise you could turn everything into some kind of factory cell that would be easy to automate and easy to interact with, in which case the sensing capabilities probably wouldn't have to be as sophisticated either, because everything is so structured. So it really gets down to dealing with unstructured environments, and I think that even as we're more capable in our interpretation of the unstructured environments I think we still need to do more in our interaction with those unstructured environments. And so that then gets into a number of issues, not just controls but also system design, and I'm hopeful that there will be some breakthroughs in the actuation and manipulation technologies that will lead us into better capabilities for interacting with unstructured environments.

Q: Do you think the kinds of research that's being done at JPL for these Mars exploration rovers and things are going to find their way into consumer applications for robotics in the future?

Richard Volpe: Possibly, but it's often that we do basic research that feeds the space applications, and some of the fruits of that basic research also can feed other directions, so it's not clear what path it would go, whether it would go through a flight project, because often what happens is you come up with a sophisticated solution, but then you have to take a reduced capability because of the limits of power and communication and computation that are on the spacecraft, so you're taking this reduced capability, but for the consumer marketplace you often don't want to take the reduced capability. But there may be counter-examples that I'm not thinking of.

Q: What's your advice to young people who might be interested in careers in robotics?

Richard Volpe: I would say that they should go for it. It's interesting. Robotics is very popular in the kind of BattleBots or First competitions, and it's not clear that those folks are staying with robotics all the way through to getting a Ph.D. and doing research in it. They're getting siphoned off to work for Google, although Google's doing robotics these days, or go to work for Facebook, and so that's much more of a computer science kind of career. Some people quipped that there's certain technologies where you say "Oh, well, they're on the cusp of creating something new or this bright future, but they're always on the cusp of doing that," and some people have accused robotics of being like that, where back in the '60s some people predicted "Oh, well, we're going to have humanoids in everybody's house by the '80s," and obviously that didn't happen. But I feel like the advances that we've seen in the last 10 years indicate an acceleration of the state of the art in robotics and that portends for great things in the next 10 or 20 years, and so someone who's interested in getting into a career that's going to be really exciting – I think if they got in now they would find themselves part of this new ground swell that's going to occur in robotics, and they would get to get in on not necessarily the bottom floor but maybe the third floor or something rather than go chase after something else, some other companies that have already grown and are matured like Internet search I think is a slightly more solved problem at this point. So if that's what they aspire to do then they're going to find out when they get to go there that all the good stuff has already been done, whereas I think that robotics – there's still juicy problems to be solved.

Q: Great. Thank you.

Richard Volpe: Okay.