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Red Whittaker

An interview conducted by
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with
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Q: Introduce yourself and tell us where you were born and where you grew up and where you went to school.

Red Whittaker: My name is Red Whittaker. I grew up in Hollidaysburg, Pennsylvania. It's a little town near Altoona in central Pennsylvania. My high school was Hollidaysburg, my undergraduate was Princeton, and my graduate work was at Carnegie Mellon University.

Q: What did you study as an undergraduate?

Red Whittaker: Engineering.

Q: Mechanical, electrical, both?

Red Whittaker: All the above.

Q: How did you first become interested in robotics?

Red Whittaker: I built a great deal as a child. I had my tools, I had a junkyard that I could pilfer, and I made things, a lot of things, and dreamed a lot, dreamed about space, dreamed about robots and built things and made them work. After my formal education, I sought something that would dent the world that I could do with my own hands that would happen in my time. I considered computing; that was a little cooked. Computing would do well with or without me and robotics – my brand of robotics, field robots, were still the stuff of science fiction dreams, fantasies, and that's the one that I chose for my life.

Q: What do you consider to be your first robot?

Red Whittaker: Well, my first robot was the explorer that entered and ultimately cleaned up the basement of the Three Mile Island nuclear reactor and that was a galvanizing experience, also an important milestone in the field robotics technology and trade. And then if we'd really trace back at the age of maybe eight I made a robotic space creature and spaceship to travel in and so it's hard to say which one of those really has the impact in my life.

Q: How did you wind up making the robot for the Three Mile Island cleanup?

Red Whittaker: I had chosen robotics, chosen Pittsburgh as the place to make it happen and speculated on what robots might be out in the world, not in buildings, not assembling and spray painting cars, and sought that opportunity to make it real and take it to the world, and Three Mile Island was that kind of opportunity, was a place that precluded humans, was a compelling motivation for need and agenda, it was local, and something had called to me. It was very purposeful.

Q: Had you already built the robot before the disaster—

Red Whittaker: Oh –

Q: – or did you build it –?

Red Whittaker: Robotics was in infancy so that idea of a full-up operational working machine was a little bit beyond belief and it was an era where there would be no research initiatives for robotics, no – certainly no research contracts in that area. So what I pitched and sold was a full-up functional working competency, a tool if you will, as though it were accomplished, as though it were available, as though it were on the shelf. And then with that charter and commission to deliver the great tool I took the money and burned around the clock for about six months and delivered the goods. It was not expected so when I delivered that robot they were a little astounded, not really expecting that there would be a robot, that it would be real, that it would be ready to go to work. And those operations and everything that it took to apply it and make a success of it was also a big part of the experience.

Q: What were the biggest challenges in the robot?

Red Whittaker: Ooh. The first was to endure. The idea of going right out of the laboratory and in to work and to operate for years without fault was above the standard. The next was that it was sealed, submersible. It was a flooded basement. It required a very forceful, effective mobility. It required that ability for operation from substantial separation and also to convey enough of the situation to an operator that it was possible to get the job done.

Q: It was a cable control system?

Red Whittaker: It was tethered, it was radiation hardened, it was very – so let me take that one again. Could you ask it once more? Was it tethered?

Q: Was it tethered?

Red Whittaker: Yeah. So it was tethered and I remembered many comments from the day that well, that's not a real robot, and I've never been too religious about what is a robot, what isn't a robot, and at the time robotics was very full of itself, a kind of a priesthood of what robots should be in an era when there really wasn't much of anything around of real competence doing anything.

Q: How did you train the operators who operated that?

Red Whittaker: So there were three volumes including maintenance and operation and then lots of training sessions and hours and hands-on and tremendous human force, human capability that was with and around this to make a success of it. And in the early days if there was that community initiative to succeed then something was possible and without that then no matter how great the technology would be the whole enterprise would go down.

Q: How many people did it take to put that together in six months?

Red Whittaker: The original cleanup robot was a children's crusade; it was an army of youth. Like many great robot teams it was maybe a head count of 25 and a dirty dozen of 13 stalwarts and 3 or 4 on the inner circle who would burn and die and give life to make it work.

Q: Were these your students or was this a company or –?

Red Whittaker: Since that whole experience was emerging from the primeval ooze, there wouldn't be the graduate culture because there wouldn't be degrees, and so these were students and enrolled from mostly the undergraduate ranks who just delivered with incredible hours and initiative and intentionality, a great craft culture going well beyond the big ideas to implementation and refinement, a great deal of testing, no boundaries for time, effort or what it would take to do the job.

Q: Did those core three or four stay with you? Did they –

Red Whittaker: Oh –

Q: – doing what?

Red Whittaker: Those three or four have gone on to be the greats so I'm sure – so one of the student leaders from the nuclear cleanup machines educated master's and Ph.D. in the trade and then went on to lead a great research group for a while, then led the Robotics Engineering Consortium for its heyday and has now recently created his company –

Q: Who is that?

Red Whittaker: Carnegie Robotics and the who is John Bares so – I'll try that again. So John Bares, a student leader of the nuclear cleanup robots, was conscripted as a sophomore, paid the dues, educated with undergraduate masters and Ph.D. under my direction, led the Robotics Engineering Consortium, and most recently founded Carnegie Robotics.

Q: Who are some of the others who worked on that first project?

Red Whittaker: One is Chris Fromme who went on to be the chief technical officer of RedZone Robotics, has built himself in many ways and is still quite active in the trade. And another woman, Leona Champeny, was a tremendous technologist and businesswoman in her day and then stepped aside professionally for one of the great – Leona Champeny, a woman leader in the team, was a great technologist, a businesswoman, then stepped aside for an early romance and to build a great family.

Q: When did you start RedZone Robotics?

Red Whittaker: So RedZone was created in 1987.

Q: We'll edit all this later.

Red Whittaker: Yeah, I'm sure.

Q: After the Three Mile Island robot what was your next big –

Red Whittaker: Oh –

Q: – robot project?

Red Whittaker: I embarked on the Three Mile Island robot in the fall of 1983, delivered it in April of 1984. That first entry into the containment building was in November of 1984. By that time the two great developments was the first of the autonomous robot excavators and significantly the first outdoor navigation machine, the Terragator terrestrial navigator, and both of those were completed in 1984. So the pace, the rate at the time, were two or three great things a year and small things more often and once embarked there was no looking back. Field robotics has never run out of great things to do, great machines, technologists, places to go, and it's not over yet and I'm not dead.

Q: Could you talk a bit about some of the other landmarks along the way? There's the volcanic exploration –

Red Whittaker: Yeah. Well, the – these robots are not apples and apples; they're not – so some robots are significant for what they do, some for the technology that's under the hood, some for where they go. So let me try that. So perhaps the biggest transformation in field robots was the mastery of outdoor navigation and that was once viewed as a challenge that was beyond reach in our time, and in an era when robots were unsuccessful moving down the hall and turning left at the first intersection field robotics was already out in the world and down in the coal mines and going up against the world as it occurs, not as faked or contrived for success. And the Terragator was the first of these great machines and its distinctions included the first navigation of a

sidewalk by camera imagery, the first use of laser scanning aboard a mobile robot, first three-tiered robot architectures, first accomplishment of continuous motion.

In the early going, mobile robots weren't very mobile. There was a lot of stepping, stopping, processing, inching, stepping, stopping, processing, sometimes a year – sometimes a foot at a time or a foot, then an hour, then a foot, then an hour depending on the complexity, and then mastering the changing of seasons, the different lighting conditions. And then there was the step-by-step evolution of trail following, road following. In the field robotics world, mines, caves are the working environments that are corridors and the enclosed, having ceilings and walls as well as the open world, and so robots in that lineage were the Nav Lab, Navigation Laboratory. That was 1986. It's a blue Chevy van, built it out in the snow, didn't have a shop at the time, and it was one of those religious moments when it gets up and goes. And then the machines that followed in '88 and '89 were the quiet development of the off-road rock trucks and the introduction and mastery of GPS to guide an outdoor machine; I actually have the first patents for that on the wall. And of course looking back there's nothing to it; you want a GPS now, you put it in your watch. There actually was a time when each channel was rack mounted and the satellite constellation was not in the sky and the estimate of position was maybe within a city block but not capable for navigation and where the window was available 20 minutes a day and the latencies and errors were beyond reach.

Q: At what point did you guys find enough to really do continuous navigation?

Red Whittaker: The timing for competent GPS navigation depended a whole lot on who you were and how you went after it and that – I first exhibited that competently in 1987 by a thread and then a higher reliability, higher speed navigation by '88 and incorporated into off-road rock trucks in 1990.

Q: What were some of the innovations in the excavation machinery?

Red Whittaker: Excavation is a penultimate application of field robotics because it took robotics into the natural world. At the time many of the AI manipulation programs were stacking blue blocks on red blocks and yellow blocks and that is a world of formal geometry and shapes, colors, whereas excavation is a little like playing in a sandbox. It's a diffuse medium and it is shaped by interaction with manipulation and then it is particulate; it's not a continuum. Moreover, it wasn't enough to use vision. It wasn't enough to just see because the working end of an excavator tool was actually below the surface and it's a problem where a great deal of force and reasoning about force mattered and at a time which was so before the capability of most of the technologies that could be applied to do that today. I can remember to get the compute power for it exploiting one of the first parallelized geometry engines and then to utilize that right in the robotic control to speculate, formulate on bounding boxes and changes in geometry and how the joints might change and to do that at a rate that would exceed the implementation of motion.

Q: You did a lot of wheeled robots but you've also done some walking robots.

Red Whittaker: Wheeled, tracks, legs, flying. I'm not religious about how to get around, mobility, yes, it's meant the world – it meant the world. Before the fulfillment of field robotics, the working world was nailed to the floor and then the transformation was to take these mobile machines to the world and to the work and there's no going back, but yes, good working – good – so walking machines have included Mars prototypes like the Ambler and if you're going to go into volcanoes Dante's a pretty good name for a walking robot, and Dante was distinguished in that it was a repelling machine so beyond walking it was a climbing machine and then coordinated the forces on its tether in such a way that it could negotiate vertical and even overhung surfaces.

Q: What were some of the challenges on those machines?

Red Whittaker: Some of the great challenges in the climbing machines like Dante were achieving the energetics and forces relative to body weight in earth gravity so in an era when actuation was not so capable and that power density was not so capable it was challenge enough to get the forces and get the forces in the right place and then to coordinate all that motion in such a way that you're not working against other motions, not performing isometrics but coordinating to do useful movement. Other innovations in Dante was the first of the spherical laser scanners, first of trinocular vision. Humans are used to getting by with two. Dante on its mast coincidently had two sets of trinocular so a total of six cameras and all the software that made that work and blended and fused the two sets of 3-D from the two sets of trinocular in order to get a composite range and then to merge that with the laser. Dante had noncontact proximity sensing in its feet so that it could sense how close is the ground without touching it.

Q: Beyond pragmatism, do you have a design principle or something that conceptually drives how you design them?

Red Whittaker: In conceiving and actualizing Dante, I performed a great number of genetic variations and determined that for its overall mission that a decapod, a ten-legged thing, was the right way to go, and there was a little part of me that just couldn't do it in part because if ten legs was the right way to go why wouldn't we see it in nature. So I built the eight-legged thing and deployed it in Antarctica and one of the great moments of that experience was on the shoreline of the ocean seeing these little walking creatures that had ten legs. So it turns out that there are hundreds and hundreds of decapods in nature; I just didn't know about them. Now I know a lot about them. But I embark with the vision that for every biological creature there is or will be a robotics counterpart and that despite all the tools and methodology for configuration and auto-configuration and proportioning and shaping of machines I apply the insanity check to see that a machine configuration as a counterpart in nature.

Q: Do you directly draw inspiration sometimes from natural systems?

Red Whittaker: Absolutely. So we – one of the great influences for me is Carnegie Museum which is 300 steps away from where we're sitting with some of the world's greatest collections of biological things, anywhere from the great dinosaurs to the tiniest insects. And yes, I study them a lot.

Q: Hmm. Can you tell me about the First –?

Red Whittaker: I learned about the first DARPA Challenge on the 14th of March 2003, which coincidentally was exactly one year until it was competed on the 13th of March 2004. So that was a clear one-year time period to go get it done. And when I heard about it, it sounded like it had my name on it. So I got a team together rand went after it. About the nine-month mark, I scraped the first dollars together and in technological challenges, you don't start with a budget and you don't ever have what you need, just what you have at the time. I brought a junk cover from a farmer and cooked some technology, got a pick-up team, and showed up in the Mojave. I was playing to win and I came off the starting line good race pace, ahead of the game, and destined for the speed and the distance. Got wind, veered off, and high-centered maybe seven miles in. And there really wasn't anything that was close, meaning that there was nothing in the field that would have the speed, distance, duration, technology to pull it off. Not sure that anyone had the competence to win that race. It was maybe beyond accomplishment in the nine months. And then a lot of the popular reaction was that it was a falling, "Oh well, it went seven miles; well, it was only averaging 15, 16 miles an hour." And that was – just built the story for the next time around.

Q: What was it that actually caused it to veer off course?

Red Whittaker: So I have the unique distinction of having rolled more Hummers at high speed that any roboticist on the planet. And in preparations leading up to the race, was really pouring in long-distance, high-speed practices and in the course of one high-speed turn, rolled that Hummer a week before race day. And so that was a comeback story coming out of nothing; long hours, pretty steep odds, and rebuilding. And the whip calibrations weren't quite right; the sensing wasn't quite on. And the difference between the orientation of the sensors in the vehicle were enough to offsite that Hummer to the outside in a curve and that was enough to go over a berm on the other side of the road, which then high-centered the front axle.

Q: And then when you came back for the Second Challenge?

Red Whittaker: Well, let's see. So how the first race worked is that nobody won and that evening, it was announced that well, it'll be competed again and will double the prize. So I deliberated and viewed that it was – that there was some unfinished business. And so this time around I got another Hummer and another team and another sponsorship and put it together and really had the dominant technology. And I had two machines that could take anything anytime, any day. I just – whatever the capability was, say in a practice or a trial, if somebody could show

a capability, I'd just notch it a little higher; capability, notch a little higher; two machines, either interchangeable. Coincidentally, I had rolled one of them, but they were ready to play on race day. Now since I had two machines, I went in with a rabbit and hare strategy and had the slower one finish about the time that I estimated the competition would come in. And to the quicker one, to beat the competition by one hour. And they were interchangeable, could go either way. So about three-quarters of the way in, the lead dog was maybe 40 mile – 40 minutes ahead gaining in every second, looking strong and lost engine power. So, if you can believe it, the Hummer engine died on me and that shockingly how it worked was that it would die to an idle and stop and then get a little bit of engine surge where it could pick up and travel almost to a walking speed and saw-tooth to a stop and then that engine'd get to a little walking speed it'll like and then it would keep that up. And it kept that up for all those minutes. And meanwhile, that slow second would keep creeping up and right before the finish line, there was the crossover. But surprisingly, even without an engine, it came in just fine. They both did within a couple minutes. And the post-race analysis showed that a fuel line, flexible fuel line was kinked. Now after the race, I got in to drive it back to the tent and wouldn't drive and looking over, saw that a fuel line was kinked and that that sharp dent in the fuel line was probably a consequence of putting it back together after the rollover. The – so…

Q: So who were your teams on the first and second race? Who were the leads?

Red Whittaker: Who were the team – the leads?

Q: Leads are your top –

Red Whittaker: Yeah.

Q: – students in the –

Red Whittaker: Great.

Red Whittaker: So the challenge race is the significant development of the challenge races was to really build a community, a world community and some of the greats from my team was an undergraduate, Kevin Peterson, a graduate student, Chris Ermson, other technologists like Dave Ferguson. And in many cases, these were people who would then find themselves in the work and commit into it and commit their lives to the future of automated – automotive automation. So these were very diverse teams, everyone from the PhDs from the robotics trade to a volunteer whose day job was with the post office. And it – to really do it the way that we did it, took a little bit of everyone; takes a village to dot that kind of thing. There's never enough money; there's never enough time to think about that kind of initiative. It really – you can't buy souls to do that work; there's not enough money to pay people off and you can't burn feet or twist arms. They play for their lives; they play with their souls.

Q: How many people altogether are on each team?

Red Whittaker: 30 was about right for the challenges and that's in part because there was a lot of mechanism – there were a lot of logistics because we were from the east and the practice in racing was from the west. That First Challenge was maybe a quarter million lines of software. The Second was maybe three-quarters of a million lines. Nah, I take that back. The First Challenge was maybe a hundred thousand liens of software. The Second was maybe 300,000. The Urban Challenge was maybe three-quarters of a million lines of software. So there's that going on. And then there – electromechanically, they're built and one of the developments for this group was to create a stabilized gimbal, a mechanical neck that would point in the best direction for the sensors to work and keep those sensors rock solid no matter what the vehicle has done under. We imagined that the races were going to be the difficult terrain and the high speed that was advertised and the long distance that was advertised. And so we trained on terrains with difficulty 5, 6, 7. Competition days were 2, 3. And in those kind of blistering terrains, we just butcher suspensions and go through tires and hammer chassis and that kind of program really called for lots, lots of people, lots of different kinds of people.

Q: And who were your sponsors?

Red Whittaker: Caterpillar was an enduring sponsor through all the challenges. And in the Second Challenge, I had the good backing of: Boeing, SAIC, a little from Intel, some from Google. In the Urban Challenge, the big dogs were General Motors, CAT, and Intel was back, Google was back. Continental was a very interesting company; they make great automotive radars. And all the sponsors are sometime sin for the adventure or the branding, sometimes in of the technical participation. And so a Caterpillar is authentically driven to the future of off-road automation. A General Motors is all in when it comes to automation and safety features for the road and they will be for eternity.

Q: Can you tell us about the Urban Challenge and how you got that one?

Red Whittaker: Chris is – the Urban Challenge was just long time later; there was a big gap in there in six months. And the Urban Challenge was announced on the second of May 2006 and then competed about 18 months later. So that's actually a long, long time. And I deliberated quite a bit before embarking on that one. By that time, it's pretty clear that the fundamentals of automated driving were mastered and that the right kind of program, right kind of team would do a good job with it. And I really didn't have a sense of any unfinished business or I – it wasn't lifted or compelled to chase it. If I were known, I'm actually not a prize junkie; and then I – for what it – I pondered a month and really did see that there was unfinished business, that just wasn't okay to have left that hanging impression of a dead Hummer engine out in the desert.

So I chased it and nailed it and really no looking back. It was a real accomplishment in the arena of behaviors, of planning that would go layers deep. The perception developments

were machines that would sense in all direction, surrounding themselves and at a high resolution and with the quality to really understand environments; of course, takes some computing to go along with it. It really built great, great community, great people. These challenges have a way of transforming belief. Before the fact, there's that sense that they're a little bit beyond reach or it won't happen in our time. And course after you do them, the world looks back and kind of, "Oh, it was nothing to that," and it gets old pretty quickly. That adage about 15 minutes of visibility definitely applies to technological challenges. And then it is a magnificent time in the robotics culture when three technological prizes occur in quick succession; that is not common in other disciplines. And so to have the Grand Challenge, the Urban Challenge, and the Google Lunar X prize… <snaps fingers three times>

Q: Can you tell us a bit about your efforts in the Google X Prize?

Red Whittaker: Google is offering $24 million for a robot that broadcasts back from the moon and I will win that. There are bonuses for going 5 kilometers and that is just sock and trade for a good robot outfit. There is a bonus for navigating to a historical location like Apollo. There's a bonus for operating after enduring the very cold, long lunar night. And the reason why that is a $2 million is that it's believed to be undoable and I've got that one nailed.

Q: Bringing a sleeping bag?

Red Whittaker: Ahh, sleeping bag works fine on Mars; Mars is pretty soft stuff robotically. You have the advantages of an atmosphere so you kind of Frisbee in, then you pop a parachute, then you float down, take all the energy out of it and then – you really can get by on Mars with a sleeping bag for a human. It doesn't get so cold, doesn't get so hot; just beautiful for electronics. Ultimately the moon is as hot as a baking oven and is as cold as liquid nitrogen and has the hard vacuum and the radiation of space and is a very challenging environment for a robot. And so a part of it like all of them is a good electromechanism, a good amount of it is the sensing which always evolves, it gets better. And then in the case of the moon, some of the tough stuff is the propulsive descent and landing. You get one chance; it is – it happens fast, it's unforgiving and it's – it controlled sensing and propulsion the whole way in. So there's a lot on the line in those few seconds.

Q: And how do you launch? Do you have to have a private launcher or…

Red Whittaker: You don't. So you – the – I'm launching with a Falcon 9; that is a commercially-built launch vehicle. Once in orbit, the upper stage of the Falcon 9 reignites to throw this spacecraft towards the moon. It then cruises for a couple of earth days, floating and then when it's near the moon, it visually walks onto the appearance of the moon and registers itself for orbiting, lines up over the intended landing site, and at the right time breaks on in. The slower you go, the more that you get pulled by gravity. And the last couple hundred meters are merely a dead vertical elevator descent where the sensing and the controls bring a very soft

touchdown. Back in the day, this style was for big linkages and a lot of mechanical absorption of energy and that's done because there wasn't enough sensing and control for an ultra-soft landing. And my bet is on the sensing and computing and the controls that'll bring it in so that a fairly rigid spacecraft is able to level and touch right down.

Q: So who are some of the people you're collaborating with on the…?

Red Whittaker: Ooh, so the – my allies for the moon are a great frontline: General Motors, Lockheed Martin, Caterpillar, Aerojet for propulsion, Harmonic Drive for locomotion, International Rectifier, one of the greatest hardened electronic firms in the world, and sponsors yet to come.

Q: And other roboticists?

Red Whittaker: Generally, the challenges haven't attracted mainstream roboticists. It's interesting that every time that I embark on a prize competition, an early move is to offer it, "This one is for you. This one has your name on it." "Well, what if I lose?" "Mm, is that the right kind of activity if I'm pursuing tenure?" Well, of course, the sure way to lose is if you don't play and prize competitions aren't for every person in the same way that they're not for every institution. So although I'd anticipate that there's a lot of collaboration yet to come, today it's a little solitary. I wouldn't call it lonely, but it's solitary. And then most of the kindred spirit is that fountain of youth that just bubbles up to go for it.

Q: Yeah, over the whole course of your career, who are some of the students that – and people that have worked for you that really stand out in here?

Red Whittaker: Oh. I don't pick favorites with students or people any more than I pick favorites with robots. It's a little bit like a really good family who have favorite kids for gosh sakes. Oh, yeah, I've loved them all, I've loved them all.

Q: But others that have gone on to be successful roboticists?

Red Whittaker: Well, here within Carnie Mellon, graduates from field robotics have gone on to lead the Robotics Engineering Consortium, the first of the tenured teaching professors, be the first to the tenured research scientists to – I'm not sure I'm saying anything here. I mean, this bus – I just am not big on picking – choosing people. So I'm sorry that that doesn't –

Q: That's okay.

Woman 1: How do you motivate them? I mean, you work with very – with large teams of people—

Red Whittaker: The first essential element of being up to something is purpose. And so, an early one that we spoke about was clean up Three Mile Island. That's a pretty wordy mission statement, probably the longest I've ever tolerated in my career. And others are win the race. And these are battle cries that call to people, not to everyone, but some people. And then the next is to get clear that it is a commitment and that we are bound in common purpose, in for the duration no matter what. The next is very clear metrics of success and that they're objective. That is something that's uncharacteristic in a great deal of research and extremely powerful in life and in technological leap, distinct from inch at a time, bite at a time, step at a time. There's more to it, and those are the basics. I'm not so sure that it is possible to motivate teams or others that do not motivate themselves. And that's why an enterprise that is intrinsically enrolling, meaning that the thing itself is the powerful draw – go to the moon for thirty million bucks. People from the world email, call, how do I play? I had – someone from China just asked how do I join the X Prize team. And I responded start swimming. And, of course, I have no idea whether I'll see that person or not, but that's how you tell whether somebody really wants it.

Woman 1: We have to meet Chris upstairs in five minutes, but what I can do is I can go upstairs just to make sure that we're not late or whatever. And you can finish up because I think that makes sense. I'll be out of your hair in a minute. What's the room number? We're not in a room. We're going to meet at the – oh, you're meeting in the cafeteria? In the lobby. Yeah. I'll let her get by here. So, I'm going to ask you about the combine.

Red Whittaker: About the –?

Q: The combine?

Red Whittaker: Oh, yeah.

Q: Go ahead. No I just wanted to say thank you very much, great meeting you.

Red Whittaker: I'm sure you'll cut something out of it. Great pleasure.

Q: Bye. Okay so –

Red Whittaker: I was a – so, I'm recalling Nomad, which is a great name for a robot that roams the desert. And Nomad is a veteran of Antarctic meteorite search, veteran of the Atacama, discovering actually the first little meteorite there and also the first fossil. And Nomad is unique in that it was a mouse done in AI as well as robotics in that it was a search engine in the natural world. So, it was the first to have a classifier and the first to learn, in this case, what's a meteorite and what isn't. And there's just so much in the mobile robot community about navigating, and avoiding obstacles, and safeguarding, and planning. And that is shallow relative to the purposeful action of a good machine. I thought about Nomad because it has maybe three thousand parts.

And they were designed and developed by two great master students Eric Rollins, Ben Shamah. They never took real jobs. They created Velocity 11, and then sold that to Agilent. But they are the roboticist's roboticists, the great builders. There's whole generations of those great ones. Robotics has taken me to all of the continents and both the Poles, out to sea, underwater, underground. And the real gift are these great people. Certainly there is something to say for the technology and the machines and what they do and how they've become successful in enterprise, and in what we do. The people really remain the great gift.

Anyway we were talking about – you were calling it a combine, so the – I came to the idea of driverless farm machines working on my own farm. And the miles are endless. With narrow equipment, it takes about a mile of driving to cover an acre. And then that's done many times a year, repeatedly, persistently over the years in the same patterns for generations. And I'm a big – I work a big land, mostly at nights and weekends. And I'm pretty serious about my day job. So, it's pushing the hours and working into dark. And I awakened being slapped by branches. And I had fallen asleep while doing tractor work and drove right into the woods. And I swore that would never happen again. And later in the same year, I woke up going very fast downhill. And I rolled a machine. And then I said this really isn't going to happen again, and considered the automation of tractors and fieldwork, and considered that this is a fairly slow. It's remote. It's not a lot of people around. Almost is good enough. And that it's an immense industry. And the rest of it really was fairly straightforward. And not too long before having the first driverless tractors together, and then that has gone on to become quite an industry. Now, if you want it, you could buy it from the factory. You can get add on kits that will steer for you, and throttle for you, and drive those impeccable patterns, miles at a time, dead straight, no overlap. It is something that really, really makes sense in the market, and one of those big changes of before the technology and after. And it's amazing that almost everything that humans have comes either from mining or farming. And field robots are making immense impact in both of those and gaining ground every day.

Q: Did any of your technology go into these commercial automated farming –?

Red Whittaker: Oh, of course. Sure.

Q: Which companies adopted your technology?

Red Whittaker: Commercializations that came from those early automation ventures included John Deere, there's one EZ Steer, which is a branded name, Trimble, others that now commercialize those features for tractors.

Q: And just to go back to the very beginning again. So, who was your thesis advisor, and what was your graduate thesis on?

Red Whittaker: My thesis advisor and mentor in life is Paul Christiano. That was in civil engineering. And the topic was a dynamic analysis of plates on elastic media, very mathematical, involved the integration of complex Hankel functions and some math, which at the time was hitherto unachieved. And now, it's so interesting to go back into the numerical packages that have that be computed in a second without a great deal of depth, but at the time challenging. Paul went on to lead a department, lead a college as a dean, lead a university as a provost, and is now deceased.

Q: And how did you start your faculty position at Carnegie Mellon?

Red Whittaker: I'm born to teach. And I came along in grad school at exactly the time when undergraduate enrollments peaked. And there was a demand for teaching. And I stepped into that, teaching much of the engineering curriculum starting as an early graduate student. And I don't mean TAing, I mean teaching the whole thing. And I credit a great deal of what I know and what I can do from the teaching of it, and of course, these great teams over years by engaging and working with students. So, when I graduated, I was offered a teaching research position at Carnegie Mellon and embarked on that. I picked up the Teare award for teaching excellence, and then moved from teaching into research as the vision of field robotics pulled on me, the work over time to create the institutions, the degrees, the education, the base of research, the literature, the identity –

Q: So, did you start out in teaching in the civil engineering? And when did you come to realize – ?

Red Whittaker: I started teaching in civil engineering, but a lot of crossover into mechanical. I was broadly capable across engineering and did my teaching in civil, mechanical, and electrical.

Q: When did you come to the Robotics Institute, or when was it created?

Red Whittaker: The Robotics Institute was created in 1979 with a corporate gift from Westinghouse Corporation. And I embarked in the engineering college as a PhD graduate in the same year, and came up developing the robots for the working world while the Robotics Institute was evolving from computer science. And then the great marriage of the two, my formal crossover was 1986.

Q: Okay, I have to run, but is there anything you'd like to add before I go?

Red Whittaker: It amazes me that field robotics has come into its own, say, in planetary exploration where there was no sense of a robot and a clear perspective that it was the realm of astronauts and heroism, and romanticism. And now, there would not be a human mission on the books. And our eyes and ears to the planets are robots. Or that field robots would be so

mainstream in the developing the world, exploring the world, securing the world, and in worlds beyond, that there's such an early consciousness for land, sea, air, space. And it's amazing to see them fulfill even underground in a subterranean world, everything from sewers to caves to mines. It's a pretty big leap for a couple of decades. Anyway, the –

Q: Any advice for young people that want to get into robotics?

Red Whittaker: I envy the timing of people coming into robotics now and reflect in many ways I was a little too early for the game, that these early work machines have been a little bit beyond the capability of computers in their time or in the early going to have to make digitizers for a camera, or controllers for a motor, or to embark without computers that could really do much of anything. And that's – if all were known, I would have done just fine. But it's amazing time and amazing decades to come. And this trade is good for lifetimes yet to come. And for people embarking, the trick is to get in the game for real, that nobody begins with a lot of mastery or even breadth across everything that matters. You start by doing something, and ordinarily it's one something that you know or where you can contribute. And then by the doing of things and by osmosis and through experience to pick up the rest of what's called for. And there's also a great advantage in starting early. So, I am from the era of the great imposters, meaning that it was before the time of robotics credentials in the same way that the Wright brothers would be before the time of aeronautics degrees. And my own life work didn't really start until the mid-thirties. And the opportunity now is to engage and immerse so wholly, and to do so from youth. That's what makes the great ones.

Q: Thanks.

Red Whittaker: Sure.