Stanford eCorner

Steve Cousins (Stanford University) – Real-World Robotics [Entire Talk]

Steve Cousins

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Steve Cousins is the executive director of the Stanford Robotics Center and founder of Relay Robotics (formerly Savioke), which builds autonomous service robots for hotels and healthcare. Cousins' career reflects a commitment to advancing robotics from research to real-world applications. In this presentation, he shares stories of his time in research, startups, and academia to illustrate practical advice about hiring, developing robotics products, and bringing robotics into new industries.

Transcript

(bright music) - Welcome, everybody to the Entrepreneurial Thought Leader Seminar at Stanford University.. The Entrepreneurial Thought Leader Seminar is brought to you by BASES, the Business Association of Stanford Entrepreneurial Students, and STVP, Stanford Engineering's Entrepreneurship Center.. I'm Ravi Belani, a lecturer in the Management Science and Engineering Department, and the director of Alchemist an Accelerator for Enterprise Startups.. Today I have the pleasure of welcoming our next ETL keynote as part of the centennial, Steve Cousins.. Steve is continuing the tradition we have this quarter of celebrating the School of Engineering Centennial by highlighting Stanford Engineering amazing contributions to entrepreneurship.. And Steve has shaped the modern robotics ecosystem more than most people probably realize.. Steve is the executive director of the Stanford Robotics Center and the founder of Relay Robotics, which was formerly Savioke, which builds autonomous service robots for hotels and healthcare.. The through line in Steve's career is he is always been passionate about pushing robotics from research to real-world applications.. He was previously the CEO and president of Willow Garage, which helped launch the open source robotics movement through the creation of ROS, the robot operating system.. How many people have heard of ROS? Okay..

So isn't that fantastic? - That's excellent, yeah.. - And if you haven't heard of it, you've probably used products that are built where ROS is really foundational.. Amazon, think about their warehouse robotics, Boston Dynamics, Cruise, NASA, a lot of their robots are built on things that are coming out of ROS.. Steve's also the founding board member of the Open Source Robotics Foundation and he's received the IEEE Award for Invention and Entrepreneurship in Robotics and Automation in 2017.. He is a triple computer science grad.. How many people are CS majors or thinking about computer science? - Yeah.. - Okay.. So Steve has his bachelor's and his master's in computer science from WashU and his PhD here from the farm, Stanford University.. So without further ado, please welcome Steve Cousins to ETL.. (audience applauding) - Thank you..

Can you hear me okay? Yeah? - [Ravi] You're good.. - All right, thank you, Ravi.. And it's really a pleasure to be here.. I saw the announcement about this talk and I said, "this has gotta be an amazing group." And so I'm very happy to start here.. I wanted to start, and I'm kind of going to tell you a series of stories that how I got to be an entrepreneur or how I kind of got to where I am and I'm just gonna go in chronological order 'cause that seems simple.. And normally, I give talks that are more robotics focused.. This one I'll try to be more entrepreneurial focused.. My career started at Washington U in St.. Louis.. And the first thing I'll say is, you know, I tried to have a nice career in a university with just a master's in computer science..

And it turns out if you have a master's and you wanna stay in university, don't do it, right? Basically, you know, the career path in universities are all tuned for PhDs.. And so I had kind of quickly, after about four years, hit the peak of what I was gonna be able to do and my boss told me, "Look, you have to either, you should think about getting a PhD." And I decided, "Okay, I'm gonna apply to Stanford and a couple other top schools and if I get into one of them, I'll go and otherwise, I'll get a real job." Academia is kind of like a fun place to be and it was the lifestyle that I wanted, but I also wanted to have a career.. One story I'll tell you from St.. Louis is I worked at the medical school there for about four years in medical informatics, and we hired this intern.. So the first theme will be about hiring.. We hired this intern for the summer, and it was a NSF funded program, so it paid, like, not very well, like, $5 an hour for the summer.. And even back then, $5 an hour wasn't a lot.. And so

he worked for the summer and he was really, really, really good.. Like, so good that we said, "You know what, can you come back at Thanksgiving just for the week? We'll pay you $20 an hour." And he came back, he was like, "Great", you know? And then we had him back for Christmas for all three weeks and $20 an hour and we, like, just paid him more than he was, you know, gonna get through normal assistantships because he was just that good.. And I tell you the story because he comes back later in my story where I work for him..

So this happens, right? You work for somebody, you hire somebody, and then later, you may end up working for them.. So keeping an intern like that, he ended up going to work at Wash U just at the time that I came out here to Stanford.. And so here at Stanford, I was working as a graduate student in computer science.. And there was a project that was getting started and one of the things that the grant that got funded had a slot for two programmers, two engineers to help out with the research.. And just about that time, I had been here for a year, maybe a year and a half, two years when the grant got funded and Scott decided, "Okay", he had enough of St.. Louis, he moved out here to to California and he said, "Can I live with you for a little while and figure out what I'm gonna do? I'm gonna do a startup." And I convinced him, I don't know if this was good or bad, I convinced him not to do a startup.. I said, "You should come to Stanford and work with me 'cause we had great fun working in St.. Louis.. Come work with me, you'll meet really interesting people and then you can do a startup", right? And it turned out that that was actually really good advice.. My classmate was Larry Page, and I know Sergei's gonna talk later in the series..

This was the time that I just happened to be here.. And Scott, because he came to Stanford as a programmer, got to help Larry and Sergei write the first version of Google, the first crawler.. So this was Google at Stanford EDU.. He never worked for Google, but it was a great opportunity for him.. And he was a very, very entrepreneurial guy.. So by the time I graduated and went on to the next phase of my life, he had already was doing a spinoff in his first startup.. So he was an example to me of an entrepreneur at a young age.. Now why didn't I just jump off and do a startup as well while I'm finishing my PhD? It turns out when I came out to Stanford, I had one kid, and when I left Stanford with a PhD, I had three kids.. So that's not ideal.. And this is a sort of a conscious life choice..

It wasn't an accident.. I mean, it was on purpose, (audience laughing) but this was a conscious life choice.. Like, you know, when you have kids, you start to meet, you know, your kids have friends in preschool and you meet their parents and this becomes your new friends group.. It's the way it works, just like when you go to college, you meet your friends group.. And so I was meeting these other dads and realizing that a lot of them who were in startups didn't see their kids very much.. And I didn't wanna do that, right? So this was nothing, it's bad or good, it's just this is not what I wanted to do.. And so I decided when I graduated I'm gonna go the industrial research route.. So I went to Xerox PARC, which was a storied place that you may have heard of, beginning of the PC and so forth.. And so, you know, this was a sort of vicarious entrepreneurship through Scott watching him do his startup company.. Meanwhile, I went a different route, let's say..

Now my choice at Xerox PARC was as a, I mean, I could have gone to an academic job, but again, I had three kids and academic jobs in the beginning didn't seem to pay very well.. My other choice was Interval Research.. And I mentioned Interval because Interval was this interesting place founded by Paul Allen, who's a billionaire.. You may know it's Bill Gates's partner in Microsoft.. And he founded this company Interval as a, basically gave 'em money for 10 years and said, "Go off and do this like a startup, but you're a research lab.. So be Xerox PARC, but without the Xerox and go off and invent some new things and see if you can make a go of it as a business." The answer was no, right? After eight years, they shut it down and that was a lesson for me.. It was like these billionaire-funded companies might end abruptly and that one happened.. And so while was at PARC, this is a picture, here you can see, the mobile robots, modular robots there, there was a guy in another lab named Mark Yim and I had the chance to move from research to advanced development, which is part of this theme.. I wasn't yet in robotics, this was probably my first brush with potentially commercial robotics.. And Mark Yim had this idea that maybe this modular robots thing he was building would make a cool toy..

So let's see if we can commercialize it as a toy.. And I was in advanced development, so I'm helping him with that.. When you're trying to commercialize something as a toy, you go talk to the toy companies.. And the toy companies have a very interesting perspective on things.. They would just tell you upfront, "This is the way the market is structured.. If you license a toy to us, you're gonna get say 5% or less.. Like, the most you can hope for is 5% of the revenues if you're basically bringing us the whole invention." We're like, "Really?" Yeah, the cost of making the toy is 25%.. The company that's making it gets the next 25%.. So if you take the cost of the bill materials and you multiply by four, that's gonna be the target price point that you would pay in a store, right? Learning that lesson was really, really important about the structure of the industry.. It also let us figure out that if we wanna make these modular robots and we wanna hit the birthday price, this was in the '90s, birthday price meaning the price that people would pay for a birthday present if you're going to a birthday party, which is like the target most price that you would pay for toys, we had to basically send it with one module..

One module.. Now one module of modular robot system is pretty boring.. And they play tested it.. Like, they created ads and they showed them against radio control cars.. Wow, look at these cars jumping over and all this stuff and then here's this modular robot and we tried to make it as cool as we could.. The kids didn't bite, the toy companies didn't bite, that project went away.. But a important lesson for me about sort of how you get things to market.. I spent a little bit of time at IBM Research and the reason I mentioned this is that IBM is very big on process.. They have process for everything.. And one of the processes they have is your career process..

And so at some point my boss, Dan Schiffman, came to me and he said, "I have to have this meeting with you.. We have to talk about your career.. Where are you gonna be, where do you wanna be in 10 years? I have to write down that we had this conversation and you have to sign it." Okay, that's the process.. But what's interesting is what I said to him, I said, "Well, in 10 years, maybe in 11 years when my youngest is gonna go to college, that's when I wanna be an entrepreneur and maybe be a CEO of a company." And he said something really interesting to me.. He said, "Hmm, I thought about being a CEO too.. And when I really thought about it a lot, I realized that I don't have the moral flexibility required for that job." And I was like, "What? Moral flexibility?" I went ahead and took CEO jobs later anyway, but it was sort of an interesting eyeopening way to think.. All right, so that's all kind of preamble to Willow Garage.. Willow Garage was a really interesting place and not a typical startup.. And I started off the story with Scott Hassan, who's the friend that I hired as an intern and then moved out here.. Well, Scott took his path, had a successful startup company called eGroups, which Yahoo bought, became Yahoo Groups..

And then he was able to invest in Google early because he knew Larry and Sergei.. And so he got those founder shares.. And so suddenly Scott had a lot of money and he came back to Palo Alto and he said, "I bought a building and I wanna start a company and do you want to join?" And he showed me the building and it was okay.. But I was like, "No." And he goes, "Well, why not?" And I said, "Well, you haven't even told me what you want to do, so how do I know if I can help you?" And that seemed to surprise him.. And so he went off and thought about it for a couple weeks and he came back and he said, "Okay, I thought about it.. Self-driving cars are really cool." This was 2006.. Self-driving cars are really cool.. We just had the DARPA Grand Challenge that you all know Stanford won in 2005.. The DARPA Urban Challenge was gonna happen in 2007.. He got so excited about this that he convinced, there were teams that were sponsored by universities and then there were some teams that were independent and he basically bought an independent team..

In other words, he went, he hired the people, and he bought them three cars and he put them into this building that he was building and said, "Self-driving car project." And he said, "Do you wanna join that?" And I was like, "Okay, I can do that." And he said, "What job do you want?" And I said, "CEO." And he goes, "Okay." That was my first CEO interview.. Yeah, it's not like exactly how I expected it would happen, but Willow Garage was interesting.. It was not a research lab and it was not a for-profit company, right? We had this mantra, let's do impact first.. We'll worry about impact first and we'll worry about returning capital second.. And we had this idea that we would spin off companies and the companies would eventually accrete value.. And that's how, you know, Scott would keep some, or Willow Garage would keep some share in them.. And that's how we would basically, you know, make money for all this work.. If it's not a research lab and it's not trying to make a product, what was this place? In the end, we decided that the best, I sometimes called it a think tank, but that's just a shorthand.. It's not really a think tank.. We called it a halfway house for wayward PhDs on their way to startups, which actually is probably the most accurate..

There's a lot of startups that came of people who came to Willow Garage and moved on.. We built this robot that you see playing pool there.. The pool playing was a one-week project.. After you had the robot and the software, it was just a proof that you could do it.. There was another project which addressed the fundamental problem of social robots or robots in the home, which is bring me a beer.. That was another one-week project.. And the robot was actually pretty sophisticated.. Like, it could open the refrigerator, get a beer, bring it.. And this was 15 years ago before we had today's humanoids.. And we made a lot of them..

We gave them away to universities.. This is one of the things that was interesting.. Scott was adamant that we wanted to have an amazing intern program.. And the first year intern class, he took us on Zero G, which is this, you know, flight where you actually do the parabolas and you have Zero G.. And the interns loved it except for the ones who threw up.. (audience laughing) And it was an interesting time because we learned another really important lesson.. We had started the self-driving car project.. Scott had another project, which was an autonomous boat.. And then I thought we need to round out the portfolio.. And I came over here to Stanford and recruited some students who were working on the Stanford AI robot..

And they came over to build the PR2 robot, that robot that you saw.. Very quickly, we had a conversation about focus, right? Because we're trying to do three projects.. Now, I came outta Xerox PARC and IBM Research where you had, you know, two projects per person, right? Because the organizations rewarded starting projects and so that you get what you reward.. But here we said we wanna focus on one thing and we're gonna do one thing well.. We tried to hire all the people who led the Stanford car project, but Google got them all.. And so instead we decided to focus on the personal robot.. The interesting thing about, this was kind of getting going in robotics, you build a robot that is super capable.. Our idea was all these companies, all these research labs around the world were basically reinventing the wheel because they all had to basically build their own hardware and then build their own software for it.. And the idea of this project was let's give out common hardware to a lot of different universities so that they can all work on the same project.. And then we had this amazing intern program where we would have, like, the first summer we had 15 interns, we only had 17 employees..

So it's a pretty amazing ratio.. So the amazing thing about the intern program was it ended up working exactly like the pandemic.. We would bring PhD students from the best labs 'cause they all wanted the robots.. So the first year when we were promising to build robots, top professors from around the world were sending their best grad students to be part of this intern program.. And after that, the interns came, they all worked on this robot operating system open source thing together.. And then that's the best platform they could work on.. So they took it back with them to their universities.. And then they told

the other grad students, "Hey, this is open source.. It works really well, you should use it." Meanwhile, we're hiring a lot of engineers to help build it.. And so after about three years of this back and forth, that idea, that germ that basically acted like a pandemic because students would graduate, they would move on to other universities, they would tell their friends..

And so very quickly the whole world was using this open source software.. And it wasn't like there was no alternative.. There were some alternatives, but they were pretty simple, right? They were like three grad students at a university had made something and open sourced it.. But if you're competing with that and you've got a team of 15 full-time engineers, your system is much more well-engineered.. And so you can see as the open source world has grown on, there's a lot of of success there.. So the robot operating system was contributions from all these students together with the core engineering stuff that we built and quickly became the standard around the world.. So when I think about Willow, you know, we had only 85 people and it was only around for six years.. And we had 130 interns, which is a lot of interns per year, if you think of it that way.. We had eight spinoff companies, three of them were nonprofits, three of them were for-profits.. Google snapped up most of them in this, remember when Google bought up a bunch of companies in 2012? A lot of them were these companies..

And the PR2 itself, we ended up making 50 robots and putting them in universities around the world.. There are some that are still in use even after 15 years, which is pretty amazing for hardware actually.. Most of the ones that are still in use, they've ripped out the computers and put in more modern computers and sensors.. And the robot operating system continues to go on.. There's a ROSCon conference that happens every year.. And the last two years, it's had almost 1000 people.. One in Denmark and one in Singapore.. So people are coming internationally in big numbers.. So this is a successful project that continues to have big impact on robotics.. But as I said, this was this weird startup where Willow Garage started, we had money, we had no name, we had no people, right? And so in order to get Willow Garage going, I tried to hire my first engineer..

I actually called Mark Yim who was on the toy project.. And I said, "Who should I hire?" And he said, "Oh, I've got this postdoc at Penn, you should hire him." And we interviewed him and we said, "Great." And he agreed he wanted to come.. And then he called us and said, "My advisors are telling me not to come because you're nobody, basically.. They never heard of you.. They don't want me to throw my career away, so I'm gonna go do something else." And so, like with Scott, who, you know, when he was an undergrad, we worked really hard to get him and care and feeding to get that first person in that lab.. Again, I did the same thing.. This time, I flew to Philadelphia, I gave a talk, I talked to all the advisors one-on-one and I said, "Hey, this is legit.. You know, like, I have a PhD from Stanford, I must be smart and we have lots and lots of money and money and smart is good, so you should send him." And somehow they said okay.. And then we started hiring.. The other thing we did, we had a recruiting lunch..

We invited all kinds of Stanford robotic students.. None of them came, but one of the adjunct faculty, Gary Bradski, actually did come.. So we didn't succeed in grabbing a student at that first lunch, but we managed to grab a faculty instead.. And then Gary had all kinds of connections.. He was the guy who did open CV and that caused us to basically start, again, bringing in all kinds of great people.. The other thing about the intern program was that after the first year since we had hired senior grad students, a lot of them were graduating and we ended up, out of those 15 students, hiring back about nine of them, either for a second internship or a number of them as full-time employees.. And by the end of Willow, after only six years, three or four of them were on the senior team.. They were now the senior people at Willow.. So it was a really interesting way to kind of get something going.. But as I said, it wasn't a real startup, right? I didn't have to raise any money..

To me a real startup means you gotta raise money or you have to somehow make money.. This company was doing neither.. So I started Savioke and the story he was asking about the name Savioke 'cause everybody calls it Savioke.. We basically named it.. We said, "Okay, in order to get this thing off the ground, we need some cash." There was a grant, there was a contract that Willow Garage had negotiated.. But Scott said, "Well, don't take that contract 'cause I'm gonna shut this thing down now." He decided he wanted to focus on one of the spinoffs and not fund Willow anymore.. So the second billionaire-funded company that ended abruptly.. So this is becoming a pattern.. So Scott was saying, "We're gonna put this down." I said, "Can I take that grant?" And said, "Yeah, you can get that grant." So I called the company, they said, "Yeah, you can do it." "How do I get that contract assigned to my new company?" "Well, you have to have a bank account, then that's all.. Okay, so sign these papers and give us your bank account number." "How do I get a bank account? Ah, I need a company..

And how do I get a company? I need a name." So that was it.. Now we gotta get like a sequence of things.. How do you get a name? A bunch of people in a room, whiteboard, let's make up a name.. We had a whole bunch of AI words on the board, like smart, clever, savvy, savvy we held onto.. And then we had a bunch of tree names is another column.. We were just brainstorming.. And at some point I looked at the board and said, "Savvy-oak." And that was it.. We spelled it funny.. Zero hits on Google, must be a good name.. Except we didn't catch that people would call it Savioke, like karaoke..

So we started this company and we had this idea.. We actually started with, unlike Willow, which started with essentially no people and a lot of money, here we had a little tiny bit of money, a few really good people who had been at Willow and who wanted to work together, and some vague ideas that we could do something in technology.. So this is like what they tell you you shouldn't do, right? Like, start with a technology and then try to make a company.. But we had a company, we had a team.. So we said, "Okay, we're gonna try it." We knew that we needed to focus.. We knew that we needed to come up with product market fit.. And we started with the hotel.. We actually had an idea of the service industry.. So this is actually a

misconception on my part, or I don't know, I don't necessarily have regrets, but I'll tell you what I now know.. I thought that logistics was boring, right? I just thought it was boring..

And so I said, "Well, I don't wanna build mobile robots and logistics.. I wanna go into the service industry, into a greenfield.. Greenfield sounds great." Greenfield is really cool except for if you wanna make money 'cause you have to solve the green.. Like, you have to figure out how to make that market work.. Meanwhile, logistics sold lots and lots of robots.. And so lots of companies that were also doing very similar technology to what we did had success because they could sell many robots at a time.. We went a different route and we said, "Let's go after hotels.. I think we'll be able to sell a lot of robots at a time." And this was based on a misunderstanding of the hotel industry and the story that, and sort of the message for all of you is when you're gonna do a startup and you're gonna go into an industry, you need to learn a lot about that industry.. You need to find somebody who works in that industry who can tell you how it actually works.. And you can go talk to people if you're pushing a product or an idea..

We had a storyboard, we went and talked to people, they got all excited about it.. We got a vice president of one of the major hotel brands, super excited.. And I understand why he was excited now, but it wasn't because we were gonna make a lot of money.. He was excited because he was gonna get a lot of PR because robots are great on camera.. And he saw that immediately.. I didn't see that.. I thought, "Whoa, we're gonna do something.. We're gonna create something real useful for you." So we put this robot, actually the picture up there is me with a Relay Robot in the Four Seasons Hotel here in Palo Alto.. And Four Seasons was one of, was the first place that we actually made this thing work.. They let us go into their elevator room and muck around with their elevators, which it turns out nobody else will let you do..

I'll talk about that.. And so we got the robot to navigate autonomously.. This was the, you know, big technical achievement, we could navigate around.. We worked with Google Ventures.. They had a design group that helped us work on the user interface, the user experience.. So we had this whole thing basically, well, there's a telephone in the hotel room and the idea of this robot is that you would pick up the phone, you would call the front desk and say, "Hey, would you send me something? Like send me a", we originally thought tooth, like, send me a toothbrush.. Nobody actually wants a toothbrush and it's worth, like, nothing.. So it turns out to be, like, a really bad pitch for a company, which another thing that we learned.. But the fact that the robot would bring it to you, I mean, there was somebody who literally we watched, 'cause in the beginning, we were testing whether the thing actually was gonna work and it was at somebody's door.. We were kind of hiding around the corner and we heard the door open and this robot, you know, experience that we had designed and the guy was like, "Holy shit, like, this is amazing." And you know, a lot of excitement in guests because they had never seen a robot before..

This is a novelty effect.. This is not the basis of a good business.. So the biggest hurdle in all of this was elevators.. And so that's why I called the talk Elevator Stories.. The first question that people asked in hotels when we said, "Well, how do we actually change the elevators?" And I mentioned in the Four Seasons that they weren't going to let us, that they did actually let us modify the elevators, but no other hotels were gonna do that.. And the reason is hotels are, elevators are considered a safety critical system, right? You're not gonna let some robot company that's coming in to try out their product mess with your elevators and potentially, you know, interfere with your guests.. I don't know why the Four Seasons let us do that, but they did.. The next brand that we were working with, the big brand from the east coast.. They were saying, "You know, you can do it, but you gotta work through the elevator company." So we started to learn some things about structures of markets.. That was a pretty important lesson..

First one is the hotels, we thought we would sell a lot of robots because we were gonna go to like say Marriott and we'd get Courtyard to do it.. And I looked it up and there's like over 2000 Courtyards by Marriott.. So we'll put a robot in every Marriott, maybe three, I don't know how many they're gonna need.. This is the story I was telling to the VCs.. We got this VP who's saying that this is exciting.. We've got this market with, you know, look at how many hotels there are.. There's 50,000 hotels in the US.. You can do the math.. You assume that you're gonna get three per hotel, it's billion dollar market.. That was the answer..

You always have to start with a billion dollar market.. But it turned out that it didn't quite work that way.. The Marriott and Hilton and Hyatt aren't gonna buy robots for their hotels, right? They actually don't have that many hotels, right? They seem to have a lot of hotels.. Their name's on a lot of hotels.. They're franchisers, right? The people who own the hotels are building owners, all different little real estate groups all over the place.. Building owners go to the headquarters of Marriott and they go to the fourth floor and they look at all the different brands that Marriott has and they pick, "ell, we're gonna be a Courtyard, we're gonna be a, you know, whatever." And the Marriott guys are not gonna buy your robots.. It's gonna be these owners.. Well, this means for us, we can't sell to Marriott.. We have to sell to building owners.. So we have to go door to door to hotels and sell one, it ended up being one robot at a time..

It was the other thing we found out once we actually deployed them was how many people were actually gonna want deliveries.. And it wasn't as many as we had hoped.. It ended up being like 15% in the US.. Now somehow, this is completely different in China.. If you go to China, every hotel has robots just like ours.. And we didn't do a deal in the early days with them.. We probably should have.. Okay, so I won't say much more about this except that there's also a market structure of elevators and you have to work with them.. And one challenge with elevators.. Elevators is the natural enemy of mobile robots in buildings, right? If you wanna go from point A to point B, chances are you have to go to another floor, you have to ride the

elevator..

And when robot gets inside the elevator and the doors close and you're talking to your cloud service that's also talking to the elevator system, you've just lost connection to the elevator sometimes, to the robot.. The robot's now disconnected from the world.. So how's the robot gonna know when to get off the elevator? Well, the system's gonna tell it a message like you're on the third floor now and the message doesn't get through 'cause you're in this closed elevator.. Then the door opens and the network reconnects and the door starts to close and the robot gets the message, you're on the third floor now, the doors are closed and the robot looks and goes, "Well, the door's not open yet.. I'll wait." And then the car gets to the fifth floor and it opens up and the robot goes out and goes to 305, which happens to be the same as 505 'cause all the four plans are the same.. It doesn't get confused.. But now it's calling 305 on the phones and standing in front of the door at 505 and you have a problem.. So we end up having to solve a lot of technical problems like that.. In this case, we end up solving it with a barometer.. The robot actually sensing the air pressure to know what height..

And you say, "Does that work?" Actually, yeah, surprisingly.. Eventually, we got so fed up with trying to deal with the elevators that we've built a robot that could push the elevator buttons itself and this is a clever idea and at the same time, it's a problem.. And the reason it's a problem is if you think about going in an elevator, there's a social situation going on, right? And so we designed the first version where the robot would go inside, stand, face the door, very quietly wait for its time to get off and then it would get off at the right time.. And that was it.. It didn't bother you at all.. But this robot, because we had to push the buttons couldn't stand still inside the elevator.. It's gonna be moving around.. So you're in the elevator with the robot, which is also, you're trying to push the button, it's also trying to push the button.. And so it's not that it didn't work, we actually deployed this in 12 hotels successfully, but people didn't like it as much, right? And then if you get complaints, you end up taking out your product.. So maybe that's the last I'll say about that..

The last thing I'll just say in the interest of time, and then I'll take any questions.. So I came back to Stanford to run the robotic center here, which, as an entrepreneur, is sort of different, right? But it's also much less stressful and also lets me be back at the cutting edge of robotics instead of having to be in sales mode all the time.. And for me, that's a good choice, right? Now, not everybody's gonna feel that way, but I'm happy to be back doing this.. The robotics center is about bringing together faculty from all over different disciplines, especially in the engineering school to create stuff, technology to help people and the planet.. But I'll just leave you with this last thing.. We have this idea of these are these flagship areas that we're focused on, which I think is hilarious because you can't really focus on five things, right? You focus on one thing.. But we have a lot of faculty, they're all focused on different ones.. Robotics is broad and there is this common core that supports them all.. So I'm happy to be back here working on robotics.. I end up talking to a lot of entrepreneurs who are trying to do robotics companies these days..

And I always ask the first question, which is what's your market? And they'll tell me, "These are my three markets." And I'll say, "Which one, figure that out first." And you know, we really are trying to be a bridge between all kinds of cool robotic stuff that's happening here at Stanford and getting things out in the real world.. So with that, let me stop and take questions and yeah, go from there.. - That's awesome.. Thank you, Steve.. (audience applauding) We're gonna open up for questions.. We've got about 10 minutes.. I wanna piggyback off of that last comment, Steve, about how everybody's now starting a physical AI is a really hot space that people are putting a lot of attention into.. One of the signature questions from the class is that if you cloned yourself and you could direct your clone to go start a physical AI startup, what area would you have it focus in on? - I'm totally passionate about senior care robotics.. I feel like the demographics make this an obvious growth area for the next two decades.. And we don't have enough people to care for all the older adults..

So if I cloned myself right now or, you know, maybe I'll decide to do another startup, but if I do, it'll be in that space.. - Okay, awesome.. Thank you, Steve.. Tiger? - [Tiger] Okay, yeah, thank you so much for your talk.. I think it's really interesting.. My question is, so ROS unified robotics software, but AI and autonomy and robots is moving fast nowadays.. If you had to design ROS all over again right now for the next 20 years of robotics, what would you change or do differently? - So actually ROS is working on, there's a project within ROS looking at how to integrate AI technologies.. I think, you know, it depends on how you, I'll say what kind of a believer you are in AI, right? There's the true believers who would say, "Sensor data in, train a lot, and actions out, right? And don't worry about anything else." And then I think there's the roboticists who would say, "Actually, there's a hierarchy there.. You wanna use machine learning where it's appropriate, but you don't wanna necessarily do everything at the same, let's say, at the same frequency, right?" Because think about you get camera data at 30 hertz, right, but you want 1000 hertz when you're actually driving motors.. And so do you wanna drive everything at 1000 hertz and can you actually make that work? So a hierarchical approach I think is appropriate and ROS actually works with that structure..

And so I think what you'll see is that various ROS packages will be replaced, let's say, open CV kind of things will be replaced by perception systems that are trained, policies, if you will.. And maybe even higher level planners, but they'll be in points as opposed to the whole thing.. - [Tiger] Great, thank you.. - Thank you.. - And if anybody else has any questions, you can queue up here.. - [Audience Member #1] Hi.. I wanted to ask sort of about your last point about research and real-world application.. So I feel like at Stanford we hear a lot about how research can become applicable in the real world for the wider community.. But can you talk a little bit about, like, the challenges or struggles that comes with trying to incorporate, like, from the academic world to actual, like, real-world applications like you were talking about? - Yeah, that's a great question..

When you're doing academic research, if you're a PhD student, if you're a postdoc, a professor, your goal is to publish and sometimes, you know, we find ourselves counting papers or you know, just, like, coming up with the next big idea..

And so the goal sometimes is let me try out the next thing and then having tried it out, I need to move on, right? And if you're a company and you're trying to do a product, you can do something over again, right? So take navigation of robots.. When we started Willow Garage, navigation was a, quote, unquote, solved problem.. And then we solved it again and we put it into ROS 1 and it was okay.. When we started Savioke, we said, "Oh, it's not good enough to actually put it out in hotels, we need to solve it again." And so you keep on improving and improving.. Technically, you can get from point A to point B, but new things matter when you actually go out into a product like smoothness and recognizing, let's say, shiny floors, which wasn't in the original paper because it didn't come up, right? But when you actually go out into real world, you know, we spent a long time as an engineering problem because one of the hospitals that we first deployed in, the sunshine came in at 2:00 in the afternoon and basically, you know, ran across this area where the robot had to go and the robot just couldn't see.. And so it wouldn't go because, you know, it doesn't go where it can't see, it's not safe.. And so it would just be stuck, right? And we end up having to event virtual sunglasses for the robot so that it could do its task.. Otherwise we have to tell the customer, "Just don't use it between two and four, it'll be fine." But that's not really acceptable.. Yeah, thank you.. - [Deanna] Hello, thank you for the presentation..

I'm Deanna, a master student studying computer science.. My question, I think you sort of answered it with the senior citizen care robots, but I wonder what industry do you see robotics being the most transformative for, so for instance, like education, I know domestic robots are a lot more popular, but what industry do you see just completely transforming robotics? - Yeah, so I mean, I think we haven't finished transforming manufacturing, but that's been going on for 60 years and I think will continue.. The last 20 years, you know, we had Amazon and we had logistics taking off, right? Basically brick mortar stores being replaced by warehouses that you order from your phone.. And so that's a huge growth area for robotics.. I believe the next area is service industry broadly.. I'm a little bit more skeptical about home robots.. I think if you really think about it and you're, you know, say two people or two people and one or two kids, there sometimes isn't that much housework to do that you would wanna spend $100,000 on a humanoid robot to do it.. But as soon as you put caregiving in the mix, as soon as you say, "Ah, I've got somebody who's got Alzheimer's in my family that I need to take care of or you know, whatever disability they may have, that they need help." As soon as you have caregiving, the economics change completely.. So, you know, personally looking for caregiving opportunities and those will happen in hospitals, those will happen in senior care facilities, but they also happen in the home.. The challenge I think right now is to figure out what's exactly needed, what does the robots need to do for people, and also what's possible and get those things together..

And what's possible is changing really fast.. But you won't necessarily replace a human, but you might become a caregiver's aide and that might take a huge load off and be worth a lot of money.. - [Deanna] Thank you.. - Thank you.. - Hi, thanks for the talk.. My name is Gosin, I've worked with Space ROS and a few other things on Artemis and the stuff that we work on kind of looks nothing like what you just showed us.. So what's the level of presentability that you kind of need to go to market or try to pitch to potential customers or investors? Because some of the work that we work on in robotics is really, you know, not very presentable at all.. Where do you think is, like, a good in-between point? - When you say presentable? - In the sense that it looks like a finished product, it looks reasonably workable in a hotel versus maybe just the hardware itself that's underpinning this? - Ah, yeah.. So it's a very interesting, like, how much policy you actually need to get something out.. We started and I kind of challenged the team 'cause there's another story that we had a meeting at Willow Garage at some point where the senior leadership team was around a big table and I realized there's this fight going on back and forth and I finally understood what it was..

And it was the software people on one side who were saying we need to move fast, we need to iterate.. And there were the hardware people on the other side saying we need, like, a waterfall model.. And I realized, like, when I started in software engineering, first thing, that first software engineering class, they showed us this waterfall model, which I had no idea what it was or why you would want it.. And they said that's wrong.. You need loops, right? Eventually, we call that agile.. Okay, but this hardware, people still believe in the waterfall, right? And for good reasons because they had to.. So we actually had this discussion and an agreement that we would try to do a new hardware prototype once a month.. That that was a reasonable path as long as I didn't expect anything out of the hardware prototype.. And by month five, we had one that actually looked like Relay and you know, we had solved how do you make skins for it? How do you make it presentable enough that we actually put that robot, this five month old prototype was the one that we took to the Four Seasons and it was good enough.. It wasn't good enough to actually work, right? It went down the hall, it was, like, wobbling and, you know, it didn't make people feel very good, but it was good enough to show off and you could show the functionality and the form and as a prototype, that was okay..

Yeah.. - Got it, appreciate it, thank you.. - Yeah, thank you.. - Thank you for the question.. I have to cut it unfortunately, gang, but you guys can ask questions.. I'll just separately to Steve after class, but we're coming up on time so please join me in thanking Steve for that awesome ETL.. (audience applauding) (bright music)..