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Hey, everyone. Welcome back to FYI, Arc's four-year innovation podcast. I'm joining you as your host, Tasha Keeney for Mark. I'm joined by my colleague, Pierce, and today we're interviewing Noa from Built Robotics. Noa, thanks for joining us. Thanks, Tasha. I'm excited to be here.
Great. We're happy to have you. I think we'll start just by quickly introducing your company to our listeners. What do you do? What stage of the company lifecycle are you at today?
Sure. I started Built Robotics in 2016. The initial hypothesis was
autonomy is common. Self-driving cars are going to be a thing, but it's going to take a little longer than people expect. It's probably going to become commercialized in more constrained environments first. I really decided to focus on construction because it was an area I knew.
I'd grown up growing construction. My dad worked in construction when I was a kid, and I worked for
him in summers during high school. I just knew there was a ton of labor out there that needed to get done on job sites, and there weren't people to do it. That was the initial hypothesis.
I think that's largely been borne out, actually. If you look at the evolution of the self-driving car industry here, we've deployed now on a few dozen construction projects around the US and actually around the world in Australia as well. What we've really zeroed in on, particularly in the last couple years, is renewables and utility-scale solar. That's our big focus now as a company. It's basically developing autonomous construction solutions for solar.
Great. That certainly fits in with the work that we do here at ARC. We care a lot about autonomy. We've done a lot of work on the autonomous taxi space. Our top-line conclusion there is that ultimately, by taking the human out of the loop, you can make the machines have higher utilization rates, but you can also, of course, lower costs and that productivity gain that you get as a result of those two dynamics can be pretty dramatic. You all build the hardware system and a software system that you can retrofit onto existing machines. Then how does that get sold into customers? I know the construction industry has its own unique dynamics here.
You're very astute to point that out. The answer is we are flexible. Like a lot of enterprise businesses, we adapt our go-to-market to fit needs of our customer. There's probably two basic models and there's a spectrum between. The first is we just rent out what we call the Exo system. That's that upgrade kit that you install on and off the shelf, Caterpillar,
John Deere, Kamatsu, piece of construction equipment. We rent that out and then we also charge a that's the hardware fee and we also charge a software usage fee. Then those two things combine together and create a RAS model, a robot as a service model. That works really well for some

customers. Then the other end of the spectrum is closer to almost being a turnkey service provider where we are training their folks pretty involved and then maybe even getting paid on a piece rate effectively or progress rate. That can work well. We've done more of that in Australia.
Then we think that there's probably going to be a spectrum where as over time, we think more folks are going to gravitate toward that RAS model, but we think that every construction company is at its own place in that journey. We're happy to meet customers where they are and just do whatever needs to be done in order to get the work done. What features made your systems particularly well suited to solar and renewables, as you were mentioning earlier?
Yeah. We have our initial product that we've launched and deployed on a bunch of different projects is an autonomous trenching solution. What is a trench? It's basically a long skinny hole in the ground and you use trenches for buried infrastructure. Pipes for water, wastewater, water for pipelines for gas or oil and water, and then also for a buried cable for telecom and for power. It's really the buried cable for power that's as merged as the use case, the end use case that's just the best fit for our technology. You can imagine where we are and the work we're doing. Utility scale solar farms are just these massive, massive projects. The biggest project we've been on was probably 20 miles by 10 miles, something like that. You can get lost out there in the desert and there's just nothing to see. These cables need to route all over that project. They're generally buried actually because of a few reasons. It's interesting to get into it. The first is it's safer. The second is you actually improve the longevity of the project because you can't access the cable. The third one is really interesting is you actually can keep the cables cooler when they're underground. The temperature of the cable really matters because as that cable's temperature goes up, the resistivity of the copper goes up, so you actually end up losing more of your power. You want to have your cables buried where they're cool, safe, and then obviously where they're safe for people who are maintaining the solar front. On that one project, there were over 100 miles of trench that needed to be installed. If you were one person to get a trench, you would have been there for years.
We have developed a system where we have these excavators, which look like standard excavators, but they have the exosystem that's installed on the back. They're tracking all over this strobsite and digging trenches and basically following the blueprints that they're given.
That was our initial product. We've gotten really good traction. The new product that we're developing is really based on customer feedback. What we heard from everybody was, hey, the autonomous
trenching is great. The productivity is actually about where a human operator is now. The quality is good. The reliability is where it needs to be, but digging your trenches is actually a pretty small slice of the pie in terms of the overall cost and complexity of building a solar farm. What we decided was we wanted to basically take on a bigger chunk of that work. The scope that we identified that we think is the best fit for our technology is what's called a power driving. You imagine that solar farm again and you have cables underground in the trenches, and then above ground, you have what are called trackers. The solar technology, which really become the dominant design in the US, is what's called single-axis trackers. You have these rows of solar panels. The rows are always oriented north-south, and what that enables is that you can rotate the solar panels. They face east in the morning, and then throughout the day, they rotate and face west. You have these hundreds of thousands of

solar panels that are all a rate on these trackers. The trackers are themselves installed on piles, and a pile is an I-beam, basically, that's been driven into the ground. Again, one particular solar farm, I think there are 300,000 piles that needed to get installed. It's incredibly repetitive work. It's very time consuming. It's also super loud. If you're on a pile inquiry, you have to wear double hearing protection, so in-ear and then over-ear hearing protection, because there's a real risk of hearing loss. We've identified that. That can be up to 10% to 20% of the cost of building a solar farm. We identified this as a really good place to focus, and we'll be launching that this summer. You've got pile drivers, excavators, you've got trenches, and the most recent acquisition of Rowan, I assume, concrete laying equipment as well. Are there any other construction equipment categories that you can claim to work in? In the past, we actually automated loaders as well, like skid steer loaders and CTLs, and then we've done a bunch of work with dozers doing finish grading. I think we've gotten to the point now where our technology is compatible with a wide variety of OEMs and types of equipment. Really, the thing that I think determines scaling and success for us is less about the technology barriers and more about how do we make something that's easy and efficient for the customer. That's where I think the pile driving is really going to stand out for our customers. You mentioned the core solution that you started with. You're reaching, you're matching productivity of a human, but I imagine that in doing that, you're reducing the labor demand on the job site. I guess, what is that as we think of the cost savings, like productivity enhancements that you all bring? How should we think of that equation, like maybe by technology or broadly now that you're handling different areas of tasks here? Maybe I can use California as a specific example. We're based in San Francisco. We've done a lot of work in California. Everybody's heard the cost of living is very high in California and wages are very high as well. If you're a skilled equipment operator, the negotiated union rate for you, including wages and fringe benefits and everything else is, I believe, $93 an hour, something like that varies a little bit between NorCal and SoCal. Then good operators in the labor shortage environment that we're in, good operators are actually even paid over scale. Above that. That's not including overtime. He turned that into a cost per year. A good operator can cost over $200,000 a year. Then on top of that, you generally have an operator who's paired with a spotter. You have an operator who's running the equipment in a spotter who's working around
the operator and giving them hand signals to let them know when they're going to deep or if they're about to hit anything. You have this team. The cost of running a production excavator on a large solar farm can be close to $300,000 or $400,000 a year in California from a labor standpoint. There's a significant economic incentive for our customers to try to bring some technology to bear here. The other piece though, which I always highlight is that you just can't find the operators. The average age of an equipment operator is almost 50 years old now and it tends to be trending up over time. You just don't have the folks who are joining the industry. Digging a trench is important. There's a ton of trench that has to go into a solar farm, but it's not the most high-touch-skilled type of equipment operating. Generally, if you want to have your skilled human operators on those tricky bits where you need to do some rework and you're digging around cables or you're in among the arrays, that type of work is the more complex work where you'd like to allocate your human labor. That gives you maybe a little bit of a sense for the numbers we're talking about here.

As you mentioned, spotters brings up a thought we were having earlier, which is when you're digging in all these dynamic environments, different soil textures and compositions, and you have to worry about obstacles underground and things like that, I imagine you have a significant sensor suite. You have to retrofit each of these. Could you tell us a little more about those sensors and how it looks like to install them and also what kinds they are?
We have, I would say, a pretty similar sensor suite compared with a lot of the self-driving car projects out there. The core of it is this liquid-cooled mill spec computer. It's a really rugged computer. It's installed in tanks and helicopters and stuff. We've got some pretty robust NVIDIA GPUs in there. Then we have cameras. We use a bunch of different monocular RGB cameras
currently. We actually don't have LiDAR on the system. We did in the past, but we don't currently. We've run into a lot of issues with ruggedness in the construction environment relating to LiDAR. Then we have GPS, and we use RTK GPS. It's basically an augmented GPS that takes your accuracy from a couple meters down to about a centimeter. It's this really accurate GPS, which is really cool. Then we use IMUs, inertial measurement units. We use those all over the system to basically measure angles and the acceleration of different parts of the machine.
That's the core sensor suite. Got it. You said that you don't think that technology is a barrier. Would you say that the autonomy for what you need it to do is pretty much a solved problem? It seems like as you deploy more and more of your solutions, you should be able to learn from those deployments and you get all that great machine vision data. What does that trajectory look like over time, or is there one? Solve problem, I think, is maybe a little bit of a stronger word. I think we've managed to solve it, but it's taken a tremendous amount of effort over the last six and a half years here. I've gone to the point now where given a new task, I feel like we can extend our platform, this hardware platform, software platform that we've developed in order to enable that task, but it takes some time. It can take up to maybe a year of R&D focused on basically extending our current technology to encompass that. We're not really at the point quite yet where we can just make an API call to a robot and then it can do some task that it's never been used for before and passed. I think we're going to be in that place for a little while. That little while could be years or even decades, but I think that what's maybe what I was trying to say before is that I think we're at the point now where the tech works and the challenge is more about getting folks to embrace the tech and make it work for them and kind of within their organizations, within their standard means and methods. That's, I think, the big focus for us. We're spending a lot of time on training. We have a partnership with the union, actually, the IUOE, the International Union of Operating Engineers. We're developing some curriculum with them to actually train operators to learn how to become robot equipment operators or RAOs. That's a big focus and then also just working with our customers to really identify, hey, this is a task that we're spending a ton of time on or maybe we're having some issues with safety or rework and our customers would like to basically explore autonomy for those particular tasks. I think that's kind of the stage that we're at now. You asked about where does this thing go? Where's the trajectory? I think that if you think back into previous decades or previous sort of eras and construction, we've kind of been able to do almost everything that we can do today for a long time. The first skyscrapers growing up in the late 1800s, early 1900s, right? They're not fundamentally that different from the kinds of things that we can

build today. What I think is different is, first of all, it's a lot safer. We have construction still a dangerous industry, but it's far less dangerous than it used to be. The second thing is that we do use equipment all over the place. If you see a job site today, you see hydraulic equipment everywhere and also battery-operated equipment everywhere. Those are kind of your two main modalities for getting work done, whereas in the past, maybe it was steam or maybe it was even mules or men who were just pulling on ropes or whatever needed to get done. I think that all of those places that you see hydraulic equipment today, that will still be hydraulic equipment, but rather than it being operated by a person, it'll be operated by a computer. I think that's what's going to change and that's how the construction industry is going to evolve over the next 10, 20 years. Speaking of safety, how exactly do you... We've heard about your eight-layer safety system that you guys integrate working as a stack of Swiss cheese, where some parts are holy, but if you line them all up on top of each other, you can't get through. What kind of things are you looking for in your eight-layer safety system and then how do you expect that the safety will be regulated for robots in the future?

Yeah. We do reference the Swiss cheese model. I also should reference or I shouldn't mention for the audience that we didn't come up with a Swiss cheese model. That's actually a sort of standard model. I think it was originally maybe from aircraft safety. It sounds a little silly, but it's actually a broadly accepted sort of way of thinking about safety and essentially just having contingency plans and trying to have uncorrelated safety solutions so that if one of them fails, then not everything does. We have an eight-layer safety system. Let me see if I can recite them all. It starts off with basically a constrained environment. We put up a safety barrier around where the robot's working, and that tells people to sort of stay outside of where the robot's working. Frankly, that's the most important one. People are pretty smart, and the main thing is making sure they have the knowledge so that they can make smart decisions. The second thing is the geofence. That's basically telling the robot, hey, stay inside the safety barrier. That's obviously important to separate the robots from the people. Then the third is signals that basically tell people who are working alongside the robot when it's actually in autonomous mode. We have these blue lights that are on and they're solid all the time. If the computer system's on, basically the exosystem's on, then they start to flash. There's a fast beeping sound when the robot's actually operating autonomously. That's kind of another warning sign that, hey, the robot's actually doing stuff right now. It's not just sitting there, and you should stay away. Then the fourth one here is we have cameras that can detect people and basically decide, hey, somebody's coming up close to the robot, therefore it should stop. We also have basically a bunch of health monitors for the robot. It can tell if maybe it's starting to tip over because it's on a very steep slope, or maybe there's an engine fault or hydraulic leak. It can tell all of those things and shut itself off and stop. We also have a system we call Guardian, where we actually have our own folks. We work with a third-party company. We have our own folks that we've trained who are constantly monitoring the robots all the time. They're almost like folks who are monitoring a closed circuit TV system, and they're providing another set of eyes and ears. Then let's see. The last piece, I think, is we have signs that you basically put up around. Again, it's all about just educating people and making sure they know that, hey, there's actually a robot here, an autonomous machine, and it's working by itself. That might have been all of them, I think so. The important thing here

is that, again, it's knowledge. We need to make sure that folks understand that there is a robot here. Every time we deploy a robot to a new job site, we actually do an announcement to the whole everybody on the site crew. They typically folks have toolbox talks, or they maybe do an all-hands basically on Mondays or something. We think that's really important. The other piece is basically making sure the robot doesn't overextend itself. We don't want it to go outside the GFNs. We don't want it to keep on operating when there's any kind of a hardware issue with the system. If you can do those two things, then we think we can actually create a pretty safe system. We're very proud that we've operated for tens of thousands of hours now with zero robot-related safety incidents from our technology. I think that one of the big things that's different about construction autonomy compared with self-driving cars is that we're operating on private land and we're operating in a place where you actually can put the robot basically in a constrained zone right there at work zone. That makes it a lot easier for us to ship a system which is safe versus having cars that are driving on public roads with varying conditions and people who pedestrians who might jaywalk right in front of the car or whatever. We think that's one of the big things that's enabled us to accelerate commercialization.
When you said a constrained barrier around where the robot operates, it sounds like it has a system in place and sensors to detect when someone's coming, but the idea is for people to stay away while it's in the autonomous mode. Does that mean that theoretically the machines could operate a lot faster than they do today or is that not how it works? I'm thinking of in factories, robots that are the non-collaborative kind that are chained off, tend to move incredibly quickly. Does it not work the same way in a construction site?
We're generally maxing out the capabilities of the machine. We're opening up the hydraulic valves as far as they go and basically moving the machine as quickly as it can go. The reason for that is that the machines are designed to be operated by humans. It's actually a pretty interesting question. What if they don't need to be operated by humans? Can they move more quickly or can some of the control systems actually start to change? I think the answer is yes, but we've decided to really stick with partnering with the biggest construction equipment OEMs rather than trying to develop something ourselves just because we stand on the shoulders of giants here. This equipment's been battle tested and proven on job sites around the world over decades now. Thinking ahead, will some dedicated autonomous equipment be created? I think absolutely, but I think we want to take our time in order to get there.
You're pushing this REO exosystem paradigm where you've got one guy who's ostensibly operating possibly a fleet of different pieces of equipment. You could go and give a robot a task at one site and then drive over to a different site, give that one a task. How present does he need to be at every site to supervise? I guess what we're ultimately trying to ask is, when can humans be completely taken out of the loop? Or is that even something that's on the radar for you guys? I guess the answer to the last question, it's not even on the radar for us. The reason for it is that there's just this work that needs to be done, this sort of peripheral to the core autonomy. That's things like fueling the machine. It's like setting up that safety barrier. It's talking to other crews on the job site and making sure that they're ready for trench to go on the ground. That kind of human collaboration we think is always going to be there. But yeah,
you might have one REO who's operating a handful of machines and getting this incredible speed up

basically as a result for the productivity and for his employer. Probably the way to think about it is maybe in a machine shop where you have a bunch of CNC machines, which are actually these highly automated robotic machines. But you still have one person who's generally tending a handful of machines. We think that that mode of working with robots extends pretty well to construction as well. In CNC machining, sure, when you set the thing off on its job, it can be fairly set and forget. But I think that there's a lot of skill that goes into the design of the toolpath and all that. In the same way, how much skill is there involved in giving the equipment, the exosystem, its tasks? Because I know you have your own software. You've said it's quite intuitive, but is it pretty basic or is it like a better operator for that software is going to get a significantly better result than somebody who's more new to it? One of the things that I guess is interesting about our work is that we don't have that much control over what gets done. That's handed to us from the site engineers who are actually designing this overall. It's electrical engineers, civil engineers who are designing this overall solar farm. Essentially, it's almost like it's such a tight specification that there's not that much room for variation. Where I think the really skilled REOs shine though is about utilization. How do you keep the machine running? How do you think one step ahead, two steps ahead, make sure that there's construction,
there's often conflicts where you have maybe the electrical crew is trying to put in a buried cable, and then you have a mechanical crew that's actually trying to stage a bunch of piles for install. These two crews can often conflict and you have to get a superintendent or a foreman out there and figure out who's going to have precedence. That type of thinking ahead and making sure that there's no conflicts throughout the whole critical path that this robot's working on, that is I think where people really shine. Then you just end up going from maybe six hours or something of productive digging. If you're not doing a great job or you can get eight or nine or 10 hours of productive digging, if you are doing a really good job managing the robot and managing the other crews around the robot. You mentioned how much it costs to hire an operator in California at least for a year. Have you done any studies that look at the
rate of equipment utilization relative to humans? Because humans need to take breaks and you do this or that. If you're designing a path or a task for the robot, essentially, then how much more efficiently can it accomplish the work and how many fewer hours are you required to rent the equipment for or use the equipment for to get the same amount of work done? Have you done any studies into that? Yeah. Typically, you're going to have two 15 minute breaks and a 30 minute break over the course of a crew if you're an operator. Plus, you're going to have times where you're not necessarily on break, but you're just not sure what to do or you're waiting. The robot just works through all of it. That's a minimum 10% speed up and a 10 hour shift. When we've seen that, I think the longest on our interrupted streaks that we've had are close to 14 hours.
The way we've done that, actually, is we even let the robot run later than a human operator would. That's something that's viable because the REOs have other activities that they can do.
This is typically something we've done in Australia where we have these super distributed sites and there's a work camp where people stay. We can even have the REO based out of the work camp and then they only drive out to the robot at the very end of the day when it's getting dark in order to turn it off. We've gotten really nice speed ups and efficiency gains there.
Yeah. Theoretically, could you run this 24-7? I mean, I'm assuming now it's coming in stages.

As you said, there still needs to be a human loop for giving instructions. Of course, you have humans in the background monitoring, but could it be an all night continuation? Yeah. I mentioned there that the REO would drive out and turn it off at night. The reason for that is actually just because we don't want to bother the ranchers who probably are never going to go there. Technically, this is their land and we want to be respectful of them. We have gotten permission on a few projects to do tests where we do 24 hours of operation or 36 hours of operation or whatever. In one 24-hour shift, we've done three times the work of a typical 10-hour shift. The reason for that is you just don't have the same kind of stop-start stuff to do every morning. We've had really good results from a handful of 24-hour tests we've done or overnight tests. You've added these capabilities through Rowan, this new product that you have coming out. Is your goal to own the own autonomy within specific job sites? You partner with the machine makers. Could you imagine? It seems like your company would be pretty attractive as an acquisition target one day. Is that what you want? What's the future that you want? What do you want Bill's ultimate mission to be? I'd like to build an independent company that understands the test time. There's a couple of companies that I think we look to. There's recent companies, I think SpaceX. Every nerd loves SpaceX. We certainly look to them and we admire that they stayed private. They're working on these incredibly difficult technical problems and then they're building real business at the same time. I think that that's the pattern that we'd like to follow. There's also a construction company that a lot of people don't know, but it's called Luterno. They were the caterpillar of the mid-20th century. I want to say they probably had 60%, 70% market share in the US in the 1950s and 60s. They eventually, I think, got acquired by Joy Global and then Kamatsu, Japanese OEM, now owns them. The cool thing about them though is that their heritage was that they actually were a contractor and they were deploying their own equipment on job sites. They were just getting this incredible, basically advantage. That was how they really proved that their tech worked. They were basically the ones who were really able to get folks to understand that hydraulic equipment was the way to do large-scale earth moving. This is in the early 20th century. I found that really inspiring. This idea of just going out there to point the robots and then making sure that they work and learning from them, I would say we've tried to follow that ourselves. I'll go out to deployments pretty often, every couple of weeks, usually. A lot of our engineering team does too. I think that trajectory of basically going out to the place that the robots are actually used and making sure you're not locked in an ivory tower or locked in an R&D lab, that I find super inspiring. It's what we've always tried to follow. I think there's just so much still. If you look at construction, it's about one and a half trillion almost in the US as a sector. It's a huge number of folks that are employed, just a huge amount of spend. If you look at everybody's share of wallet, their mortgages or rent tends to be the highest. I think there's this incredible amount of construction that needs to get done. I think autonomy is going to be a really big lever for us as a society to get people better constructed, better built world infrastructure at a better price. Would you eventually want your system to be factory integrated, built purposely, built onto machines? It seems like right now, you need to go after this aftermarket solution. That's even what we see the other construction operators that are working on, pieces of autonomy doing themselves because of the way that product life cycle works. Eventually, you think it could all

be integrated. You can tell them I like history and I like looking at patterns from previous eras. Something that I compare our trajectory to is actually steam ships, paddle wheel steamers. For a very long time, ships actually would have sails and then also steam engines and paddle wheels on them. That was the standard way of making ships for a period of decades. It looks silly. It looks super silly. Actually, now, if you look at some of these photos, it's like, why did they need this? It's because sails were this trusted technology, the ships that had already been designed. In many cases, they'd already been manufactured. Ship's super expensive. It's not like you're going to go make a new one. They're going to retrofit it. Or you would make a new one. You'd want to have both capabilities. I think we're in that same period now in autonomy and in construction equipment. I think that for the next 10 plus years, we're going to have excavator that's got a cabinet and joysticks. You can put a guy in there and operate it from the old-fashioned way. Over time, we're going to get to the point where we have purpose-built, dedicated, autonomous construction equipment as well.

Yeah. That reminds me of, it's like the transition from the horse to the automobile. There was some similar things going on. It's like you had a semi-automated machine, but it was still being pulled by a horse. It did look silly, but I guess that's what happened in the interim. Yeah, exactly. Do you think that in terms of the components that you need for autonomy, is that always going to be off the shelf? I see some of the autonomous car companies going after it. Well, I guess some of the companies that are using LiDAR at least want to bring that in-house. I know you're not using that, so not relevant here, but in terms of the sensors that you need or perhaps the hardware that you're using for inference, would that always be just partnering with outside providers?

I think so. I think it's, if you're Google Waymo, maybe you have the budget where it starts to make sense for you to just try to spin up your own LiDAR division, but arguably, I'm not even sure if it really makes sense for me, but I think that it does not make sense for us at our scale and sort of with our financials. I think that a question that is always important to ask is, why now? What is the thing that's enabling your startup to be successful now? It's an important question because if there's not a good why now, then maybe it's not a good startup idea. I think that the answer for us is that there's just so many pieces of technology that didn't exist five or 10 years ago that we're now counting on. It's the cameras, it's the algorithms, it's the GPUs, the CPUs, it's even the IMU sensors. All of these things are really, the self-driving car industry, I think is propelling a lot of it, but it's beyond that too. It's even just the continued improvement from cell phones and obviously all the research that's being done in ML, all of that I think is blending together to basically give us the point now where all the Lego pieces are kind of out there and then we're really much more of like a systems engineering kind of company where we're taking them all, gluing them together, creating good architecture, creating good UI, and that's how we're adding value for the customer.

So as you become more and more competent at doing this kind of systems engineering, do you expect that sister fields like agriculture or things like that will become more easily accessible to you or do you expect you're going to remain within construction? How do you see that looking?

I think yes is the short answer. A lot of the equipment is fundamentally similar and the tasks are not that different either, but I think that the economics are pretty different,

particularly between agriculture and construction. And there's this, I think a McKinsey study that was done a couple of years ago that basically looked at the labor productivity in different sectors of the economy and the number one improvement since World War II was actually agriculture. We have these giant tractors and combines, we have GMO crops, we have improved irrigation system, all different kinds of things. And so the effect is that it just takes so little labor now to create food that very few people are employed. And we were actually on a wind farm project for a few months and the wind farm was situated sort of within a corn farm in Kansas. And I was talking to some of the guys who worked there and it was like a 500 acre farm that had three people who worked there. It's like there's so little labor that's required in order to do this work now. And if you look at construction, construction is kind of crazy, basically like it's the opposite, where instead of it being more efficient compared to the World War II, it's actually less efficient now, where it takes more people to sort of create the same amount of, if you want to go build another empire state building, it's going to take you more people and more time. And would you say that's because of safety restrictions or restrictions or why would you say that? Exactly. I think that that's part of it. I think that other regulations are part of it too in terms of just zoning and environmental and things like that. But I think that the biggest reason for it is that the cost of living has just continued to go up. And so you have to pay those wages in order to attract people into the industry. And the means and methods haven't really changed.

It's kind of like what I was saying before is that the things that we can build haven't really changed that much. And the biggest, I would say that probably the biggest innovations are like, yeah, battery operated, it can't have equipment and then hydraulic equipment.

So you just haven't had the same sort of like improvements that you've seen in agriculture and manufacturing in other sectors. So to answer your question, we'll be sort of look at some of these adjacent sectors. I think we will and we have to some extent, but I think that there's this incredible pent up need in construction, which I think sets it apart really from every other sector out there. And in the passenger car space, when you, like the data stream that you get off of collecting images and video really helps you solve all these corner cases. And it's this huge asset. And I imagine that it is for you as well. But it must be, it's slightly different because you don't have those surprise factors that you talked about where you would with like an on road system. Do you think that it's, in your case, it's more like this helps me one have like these proof points to help with the adoption of the technology that maybe also expand into other tasks or does that, how do you think of that asset that you're building? Yeah, I think that it's, I would say it's tremendously useful for us, mainly in the sense that like, it's not necessarily that we're like running all of this whole data set through some like machine learning, like in a training process, but it's more that we just have hit all of these things and we've kind of like baked them into our system, all these different edge cases and challenges. So I think it's more of like a traditional way of valuing that asset where, you know, if you've just done a bunch of trials and you've deployed it a bunch, you're going to have a better system versus the self driving cars. But that said, I mean, we still have, you know, I want to say a couple million different images that we've collected from a bunch of different job sites. And we, you know, we do sort of feed them off through our machine learning models and, you know, we back test on it. And so that's, that's helpful too. But I think

that because of construction being a more constrained environment, yeah, you don't have to worry quite as much about that. Or another way of saying is that, you know, we can have a machine learning system that's basically tuned to like, what's expected. And if anything deviates from that, then like, oh, wow, we got to stop, right? That's, that's one of our triggers in our eight later safety system. Whereas in, you know, self driving cars and public roads, you can't be that conservative, or you're going to have way too many false positives. So it's a different way of architecting. We are in this kind of golden age of AI and machine learning, where we're seeing all these crazy advancements, you know, chat GPT, and it seems like some of that, like it has to be somewhat pervasive and like make its way into other fields. And what we're initially seeing now, like you can imagine, you know, you're getting like some sort of voice input into, you know, a machine that wasn't really possible before. And I've also seen that, you know, Tesla's using transformers to basically predict where lanes are as you, as the car is approaching, before it sort of understood, can actually see what's happening. So I'm just curious, like, what, what types of AI you're using today and have any of those advances helped you as, you know, you've built your, the company. So we really use machine learning for perception, you know, for computer vision, basically. And yeah, we definitely are continuing to see advancements there. You know, one of sort of like, you know, a lot of people are focused more on things like language models, especially with chat GPT over the last couple of months. And I think there's a bit of a perception in academia anyway, that like, computer vision is kind of a solved problem for machine learning standpoint. That's not how I think about it. And the reason is like, it's just how many nines do you want, right? And it's fine if you maybe only want like, you know, 90% accuracy, then yes, sure, you know, computer vision is a solved problem. But, you know, 90% is not good enough in an actual commercial application where safety is online, right? You need like, five nines or six nines or something. That's what we're really focused on is really how do we refine our machine learning model in order to get us that many nines. I'm going to do it without introducing these false positives. So I would say that we're not necessarily using like maybe the, you know, chat GPT is not a part of our system, at least not yet. But I do think that there are, we've been continuing to benefit from advancements in the sort of machine learning field. And yeah, it's absolutely one of the things that enables this technology to work today. Maybe one last thing on my mind, I don't know if we have time, but worth exploring a little bit about why we're focused so much on solar today. And I think, you know, the tradition to solar is, you know, something that we need as a society. And the other thing though that I think is really cool is the IRA, you know, the inflation reduction act that, you know, was passed last summer, I think it's meaningfully shaped like the construction industry and a lot of different EPCs, these sort of large engineering procurement and construction companies have sort of refocused their business around solar because of the IRA. And so we've seen that too. And, you know, a lot of, I think in 2022, something like 15 or 16 gigawatts of utility scale solar was installed in the US. People are now projecting that by 2030, it's going to be like 120 gigawatts or something. So we're going to see almost an order of magnitude increase. And a lot of that is actually due to the IRA. So, you know, I tend to probably be more on the side of like, you know, we don't necessarily want a ton of like government intervention in a lot of industries. But I think that the IRA is actually, to me, it's just a fantastic move. I think that the fact that we are finally focusing, we have the budget to actually spend on transitioning to renewable

energy, I think it's pretty cool. And so that's, and it's, you know, meaningfully changed our strategies of company. So that's why, you know, you think in your next generation product, you're focused on this area. It's like, it's becoming more important for that reason. Yeah, exactly. And I think that, you know, when you're making decisions at the board level, like you're looking a lot at like TAM, like your total addressable market, and the fact that the solar industry is growing so fast, and, you know, we'll continue to grow so fast, is basically lets us sort of make a financially responsible, dedicated bet to solar, which is what we're doing now. Great. And what's next? I mean, as we, you know, we have a few minutes left here, as we're wrapping up, what are you most excited about? What should we, you know, as students of innovation be looking out for for you all? So I think that, you know, with our autonomous trenching solution, and then our autonomous piling solution, that'll let us actually take a, you know, big chunk of solar and, you know, put it into our system, and, you know, our robots can actually help in a big way, you know, build a utility-skilled solar farm. But I think there's actually even more for us to do, too. So, you know, we're starting to think a little bit about material management on the site, and, you know, moving material around. It's a big challenge because you have, you know, just like 18-wheeler is all day long that are coming in and delivering parts and components, and then it needs to all get sort of distributed across this massive site. So that's a focus for us, and then actually handling the modules themselves, the solar panels themselves, and getting those in position to be installed on the trackers. So that's another big focus for us, too. So, yeah, I think really, I also should say, too, I think that solar is an exciting place for us because it's grown so fast, and, you know, the IRA and everything that's powering that. But it's also, it's a sector of the industry, which is new. You know, the, I was talking to somebody recently who worked on the largest solar farm in the world, or sorry, in the U.S. a few years
ago, it was like a five-megawatt solar farm. And to give you some sense, like the biggest solar farm in the U.S. now is over a gigawatt. So, like, you know, 200 times that. And it's only in, like, a decade. So it's just this, it's this sector that's developing so quickly that I think people are really excited and open to embracing automation, too. So, yeah, basically doubling down on solar and,
you know, looking at all the different ways we can help.
And does, I guess, because of its newness, does it give autonomy kind of more of a chance because you're reconsidering the job, it's a new job site?
Yes, absolutely. And there's less, yeah, I would say there are, the people are definitely kind of, you know, hey, this is how we built solar farms for the last five years. So, like, you know, we don't want to change that much. But it's a lot easier saying, hey, this is how we've done it for the last five years, then this is how we built, you know, apartment buildings for the last 50 years, right? So the people are, the ruts are not as deep, I would say, in terms of how people like to operate. And solar is also, it's, if you go to a solar farm, it almost looks like a fractal, right? It's like this sort of system that's, you know, very simple, and then just stamped out, you know, a million times, you know, over many, many acres. And that, that also I would say is conducive to autonomy because, you know, robots are great at repetitive work.
That makes sense. Well, Noah, thank you so much for enlightening us today. We learned so much about Bill Robotics and all the exciting things you're working on. We're excited to see,

you know, product. And I think thanks for sharing it with us today. Sounds like there's a lot of exciting developments happening in the solar space. So definitely something for our listeners to, to watch and look for. Well, I, you know, I'd like to thank you for coming on the ARC Invest podcast. And I hope, I hope we continue the conversation in the future. This has been great. Thank you, Tasha. Yeah, thanks first. Appreciate you guys making that time.
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