EPISODE 595

[INTRODUCTION]

[0:00:00.3] JM: Self-driving electric cars will someday outnumber traditional automobiles on the road. As transportation becomes autonomous, it's hard to imagine an industry that will not be affected by the downstream effects of this change. These cars will likely be managed by fleet operators, like Lyft and Uber. We will need fewer cars and the amount of space dedicated to those cars will shrink dramatically. Parking lots, massive roads, gas stations, these will all be reclaimed, or repurposed. City planning departments will have to devise entirely new strategies as the self-driving cars reach consumer availability, an intricate supply chain for these cars will develop.

When smartphones became a mass-produced, the cost of GPS devices, accelerometers and other small components drops steeply. One consequence of the smartphone supply chain was that other devices like consumer drones became affordable. The self-driving car supply chain will lead to the mass production of building blocks for other new devices. With fewer automotive fatalities, the economics of the car insurance industry might collapse completely. At a minimum, the costs of car insurance will likely shift to the fleet operators who can purchase that car insurance at prices factoring in their large risk pool.

Frank Chen is a deal and research partner with Andreessen Horowitz. In a series of presentations on the autonomy ecosystem, Frank explores the effects of our impending shift to self-driving electric cars. His analysis considers changes to energy infrastructure, the competitive landscape of software companies and a range of other topics. Frank joins the show today to discuss autonomous vehicles and the side effects of widespread autonomous deployments.

If you enjoy the show, I recommend checking out his series of presentations on the autonomy ecosystem. It's on YouTube and there is a link to it in the show notes.

[SPONSOR MESSAGE]

[0:02:08.3] JM: Azure Container Service simplifies the deployment, management and operations of Kubernetes. Eliminate the complicated planning and deployment of fully orchestrated containerized applications with Kubernetes.

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Integrate with your choice of container registry, including Azure container registry. Also, quickly and efficiently scale to maximize your resource utilization without having to take your applications offline. Isolate your application from infrastructure failures and transparently scale the underlying infrastructure to meet growing demands, all while increasing the security, reliability and availability of critical business workloads with Azure.

To learn more about Azure Container Service and other Azure services, as well as receive a free e-book by Brendan Burns, go to aka.ms/sedaily. Brendan Burns is the creator of Kubernetes and his e-book is about some of the distributed systems design lessons that he has learned building Kubernetes.

That e-book is available at aka.ms/sedaily.

[INTERVIEW]

[0:03:43.4] JM: Frank Chen is a deal and research partner at Andreessen Horowitz. Frank, welcome to Software Engineering Daily.

[0:03:49.2] FC: Thanks so much for having me, Jeff.

[0:03:51.7] JM: You've been looking at the trajectory of a world with self-driving electric cars, as well as some of the downstream secondary and tertiary effects of that change. Why did you start studying this area of self-driving electric cars?

[0:04:08.4] FC: Well, the first thing is it's actually my day job. I have the funnest job in Silicon Valley, I think, which is when entrepreneurs knock on the front door and ask for money, I get to open the front door and ask them what do you need the money for? I ended up seeing a ton of startups in the self-driving space. My day job is to help figure out if any of these are investable.

I started looking at how will the world change and how will that create room for startups and which one should we invest in? That's how I got started. As I got deeper and deeper into this rabbit hole, it was just more and more fascinating how the world is going to change when the world changes to electric self-driving fleets, instead of us driving around our gas-powered cars.

[0:04:55.5] JM: The first revelation that you come to in this series of presentations that you've given, I'll link to these presentations by the way in the show notes. These series of presentations you gave on autonomy, which are a summary of some of the research that you've done. Your first revelation is that this will happen faster than we expect. Why will large fleets of self-driving electric cars be on our streets faster than we expect?

[0:05:23.6] FC: The short answer to that is economics. The way to think about it today, is if you own and operate your own car, it costs you about 80 cents a mile of travel. If you don't own and operate your own car and you just decide to Lyft everywhere, that'll cost you about a buck fifty a mile.

There are analysts that are predicting that self-driving fleets will get to parity with owning and operating our cars in the next, call it five years, and by the next 10 years, it will actually be cheaper to be driven anywhere. Call it 50 cents a mile, versus 80 cents a mile. When that happens, I think we're just going to see a massive change, which is look, it's cheaper to get driven everywhere you want to get driven. Why do you want to sit in gridlock? I think that the short answer to this is it's going to be cheaper.

[0:06:15.8] JM: The first downstream effect of that cheapening and that widespread penetration of self-driving cars that you evaluate is public infrastructure, public infrastructure like roads, parking lots, medians. Why does public infrastructure need to change in response to that economic change in that large penetration of self-driving electric cars?

Well, the way I think about this is there's an awesome opportunity to change the shape of our cities. There's really only been three chapters to date in cities in history. Chapter one is we built cities and we walked around in them. Then chapter 2 is we brought the horses in and the carriages in. Then chapter 3 is we brought the cars in first on surface streets and then we drove the free ways to them. As we head towards self-driving, we now have the opportunity to completely rethink how we use the real estate.

A couple fun things will happen when we switch from driving our own cars around to mostly fleet operation, especially in the big cities. A fascinating stat I found while doing the research is LA is 14% parking lots, 14%. Imagine you could walk into the City Planning Office of LA and say, “I have a magic wand and when I wave this magic wand, 14% of your land is coming back to you,” because we don't need parking lots. When we have fleets, they will always be either delivering people, or getting to the recharger, or delivering stuff, right? They're never just going to sit idle.

As a result, parking lot space in cities can approach zero. You go from 14% to 0% and just think about the opportunities. What are we going to do with that space? I'm going to do a plug for people starting programs in urban design, because I think over the next couple of decades, urban design is going to be one of the most fascinating and rewarding careers there's going to be. Because think about taking that magic wand and then actually writing the zoning laws and doing the economic development to go from 14% parking lots in LA to zero. What are we going to do with that space? I'm hoping there's a lot of creative people out there who have ideas and will now get to exercise them.

[0:08:33.1] JM: You predict that these self-driving electric cars are going to mostly be managed fleets, rather than the model of owning your own self-driving car. Do you anticipate any of these fleets being publicly owned? Are they going to be owned by government entities and paid for by taxes, or are they going to be private entities?

[0:08:57.3] FC: We talked to a lot of public officials, governors, mayors, and so on and so forth. I don't hear a lot of them clamoring to own and operate these fleets. One, that would be expensive. Then two, ultimately I think the fleets are going to come down to who can deliver the most delightful user experience.

If you think about ride-sharing today, a big part of the delightful experience is there is a Lyft car close to you, right? The time it takes for that car to get to you is a part of the experience. There will be other things that determine how delightful a fleet experience is, like does it remember what Netflix movie you were watching in the last car you were in? When you step into this car, can it really pick up where you're watching?

There's going to be lots of ways that the fleet operators compete for your business. If you think about governments, they're not really ideally suited to deliver a great user experience, right? That's not what we want our governments to do generally. I think governments can play a huge role, and this is both local and state and federal.

One, I mentioned urban planning. What are we going to do with all the parking lot space and other space that's coming back to us? By the way, all the DMVs, that space we also get to reuse, because nobody will need driver's licenses anymore. We can re-harvest that space. As planners, they're going to be valuable as rule writers. In other words, what are the new rules of the road? They're going to be super important, right? We get into an accident, who's liable?

Then as organizations that can offer economic incentives like R&D tax credits to both the incumbents and startups in this space to encourage development of self-driving technology in their jurisdictions, that's great. Governments will play an important role in getting us to the future that we want with, which is these self-driving fleets, but I don't see them primarily doing that as owners and operators of the fleets.

[0:10:53.5] JM: When these cars start scaling up in quantity, the supply chains for the self-driving electric cars are going to give birth to a completely new industry, or at least scale up and change existing supply chain industries. Trying to predict exactly how that supply chain is going to look is impossible, but there are some existing supply chains that we can look to as examples. There's Airlines, there's the existing legacy car creation and supply chain, there's the smartphone supply chain, which was something quite new. What are the lessons that we can draw on from those other supply chains? When you look at the impending self-driving car supply chain, what are the previous examples that you think will set some precedent for what this is going to look like?

[0:11:49.3] FC: Yeah, so there's two analogies I want to draw out here. One analogy is the airlines. If we shift to fleets, we could end up with an ecosystem that looks a lot like the airline ecosystem. You have a very small number of manufacturers, say Boeing, Airbus, Embraer. Then you have a larger number of carriers; United Delta, Southwest, etc. You as a consumer, your primary loyalty is to a carrier, because they have your miles, they are in your hometown, they have the most flights that you want. You don't really much care if it's a Boeing or an Airbus, you care much more if it's a 9:00 flight, or a 3:00 flight.

We could just see that dynamic play out as we shift to self-driving fleets, which is your primary loyalty would be to Lyft or Uber or DD, depending on where you live. We probably see a smaller number of manufacturers, right? Today there's maybe a hundred auto manufacturers. I don't know if we need a hundred manufacturers if they're mostly providing the fleets. Then we have these companies between the manufacturers and the fleet operators. In the airline industry, there's these giant leasing corporations that buy the planes and then lease them to the carrier.

An example of this would be GE Capital Aviation Leasing is an example of one of these leasing companies. We may see the emergence of leasing companies that are the intermediaries between the manufacturers and the fleet operators. Now the fleet operators may decide to do this themselves, it depends on whether they want to carry those assets on their books. That's mostly a business model question for them to answer. We could end up seeing a supply chain that looks a lot the airline supply chain. That's one analogy.

Then the other analogy that we're starting to see even with the incumbent on auto manufacturers is the smartphone supply chain. Today, what you see is you see carriers in conjunction with Apple, or a phone manufacturer offering, essentially phone as a service. They bundle together the cost of being a network customer and the depreciation on your iPhone together, right? Together you pay, I don't know, a 100 bucks a month or whatever and you have phone as a service.

The card companies are seeing this as a shift in consumer sentiment, and that's what they want to buy. They've started to offer car as a service. You have services like Care by Volvo, or Book by Cadillac, and they're essentially car as a service. You pay a monthly fee and it includes the

lease, the insurance, the maintenance and so on. Gives you a lot of flexibility to get in and out of different cars depending on the program.
I think that's another model that we can look to. Either there will be a per ride model like there is with Lyft and Uber today, or there might be a subscription model, which is essentially all you can drive or be driven I suppose is the way to think about it. That might be a way we end up paying for our transportation is a monthly fee, not unlike Netflix, or not unlike phone as a service, and we get driven everywhere for whatever it is, 50, 100, 150 bucks a month.

[0:14:58.4] JM: The hardware supply chain is something that I'm curious about, because with smartphone production, you had these downstream effects where the cost of all the components that went to a smartphone got driven down. You had GPS and accelerometer and other small devices that were now being produced on mass. That made it easier for people to build drones and other devices that are not in as high-demand as smartphone. Because of the economies of scale that came with the smartphone, you actually had new industries being given birth to. As the self-driving car supply chain ramps up, is that going to increase output of any smaller components, or some building blocks that were previously scarce?

[0:15:47.3] FC: Yeah, for sure it will. One, the smartphone industry and as you observed, all kinds of components just seemingly appeared out of nowhere in the supply chain, like GPS. First, the cars will be a big beneficiary of all of these components. We jokingly call it internally this is the peace dividend of the smartphone wars, right? As Samsung and Apple and all of the manufacturers went to war trying to get you to buy their phone, the component manufacturers were big beneficiaries. The cars will use a ton of smartphone components.

The GPS, the accelerometers, the GPU graphics processors, and the smartphone CPUs, all of these components will just get directly used, so that's awesome. Then the self-driving car industry will also have lots of other components that it needs. Examples of these would be Lidars, these are the Kentucky Fried Chicken-size buckets that you see on top of the self-driving cars today that are spinning. These are essentially 3D radars that allow the cars to see very accurately what’s around them. The best of these systems can see a basketball at 400 yards in full 3D, right?

Those types of sensors will get to scale on the back of self-driving cars. There's a set of people who also say, so-called V2X radios, so V2X is the fancy industry term for V2V, that's vehicle-to-vehicle, that's one car talking to another, or V2I, that's the vehicle to infrastructure, that's a traffic light talking to your car, right? There were the all forms of new communication that's possible. Why would a car want to talk to a car? Well, a car would love to talk to another car if for some reason its brakes failed and it needs to communicate to the rest of the world, “I've lost the ability to break, so please get out of the way.” That's a great example of where a V2V radio would be super helpful. These components will also appear in the supply chain and get to volume on the back of self-driving cars.

[SPONSOR MESSAGE]

[0:18:05.0] JM: We are running an experiment to find out if Software Engineering Daily listeners are above average engineers. At triplebyte.com/sedaily you can take a quiz to help us gather data. I took the quiz and it covered a wide range of topics; general programming ability, a little security, a little system design. It was a nice short test to measure how my practical engineering skills have changed since I started this podcast.

I will admit that, though I’ve gotten better at talking about software engineering, I have definitely gotten worse at actually writing code and doing software engineering myself. If you want to take that quiz yourself, you can help us gather data and take that quiz at triplybyte.com/sedaily.

We have been running this experiment for a few weeks and I’m happy to report that Software Engineering Daily listeners are absolutely crushing it so far. Triplebyte has told me that everyone who has taken the test on average is three times more likely to be in their top bracket of quiz scores.

If you’re looking for a job, Triplebyte is a great place to start your search, it fast-tracks you at hundreds of top tech companies. Triplebyte takes engineers seriously and does not waste their time, which is what I try to do with Software Engineering Daily myself. I recommend checking out triplebyte.com/sedaily. That’s T-R-I-P-L-E-B-Y-T-E.com/sedaily. Triplebyte, byte as in 8-bytes.

Thanks to Triplebyte for being a sponsor of Software Engineering Daily. We appreciate it.

[INTERVIEW CONTINUED]

[0:20:02.8] JM: When you think about the design of these vehicles, where we are today is, it was either you or I think Benedict Evans I heard talk about the idea that when the first cars came out, they looked horse-drawn carriages with no horse. The self-driving cars we have today look like human-driven cars without a human in them. Similarly as the horse-drawn carriages without a horse slowly transformed into what your Honda Camry, or Toyota Camry looks like, we will have a advance in the design of what a car looks like.

You can remove the steering wheel, you can remove the pedals, you can remove the hand brakes and that frees up all this space inside the car. What can you do with that change in the physical space within the car?

[0:20:58.7] FC: One of the things that I think will take the place physically of call it the user interface components, right? Your brake pedal, your steering wheel, your speedometer is giant screens, we're already seeing that in the new Teslas, which is they have almost these comically large tablet-like looking computers. Imagine that you could replace your entire windshield with a touchscreen. Since we're not going to need to see outside these cars, we can be watching Netflix.

I think most of it will become what looks an enormous tablet computer. This is already happening, so one of the things I say is that the carness of a car is less of buying criteria for buying a car these days, than the smartphoness of a car. What I mean by that is when I grew up, if you were a car head, you would know the 0 to 60 acceleration time, you would know the braking distance, you would know whether your car had a double wishbone, or a multi-leak suspension. You knew all this stuff, because the carness of the car was very important, because all of those things directly related to how it felt like to drive the car, right?

BMW is the ultimate driving machine, because they pay attention, excruciating attention to all of these details, to make it feel awesome. Well look, if you're not driving the car, none of those things are important anymore in the same way. The attention will shift to the smartphoness of

the car. In other words, how big a screen, how responsive the touchscreen, did it remember where I was in my last app, right?

You can already think of Android Auto and Apple CarPlay becoming the dominant things that we use to decide whether to buy car A or car B. I think in the future those things will be a big part of the decision of whether you're going to take a Lyft or an Uber, is how delightful is the user experience? Not how awesome are the car bits.

[0:22:56.5] JM: Have you closely examined that Apple CarPlay versus Android Auto, I don't know anything about those.

[0:23:03.1] FC: Think of them as the user interface for that big touchscreen in your car. The battle royale happening right now is the car manufacturers are trying to build better and better, what they call info, or info entertainment systems in their cars. One of the funny things is if you read consumer reports over say the last 10 years, these things, the infotainment systems have become increasingly important criteria along which the cars are getting graded.

It's very typical for consumer reports review now to say, “Hey, look. This car is awesome. It brakes fast, it drives fine. All that is good, but the touchscreen is really slow. As a result, we're not recommending that you buy this car.” It's super interesting to see basically the race is on for the user experience, because cars are all pretty good now. In that race, you basically have the auto manufacturers racing against Apple and Google to deliver a delightful user experience driven by touchscreens.

You know what? I'm long Apple-Google and short all car manufacturers in this race. Car manufacturers just – they don't think about delivering great digital experiences, because they got their hands full trying to build great cars, which is very hard by the way. Apple and Google, which are offering Android Auto and Apple CarPlay, which are essentially user interfaces that take over these big screens in your car, this is all they do, right? For them, this is a slightly bigger smartphone screen, awesome. That's exactly what they are great at.

In this race, I'm definitely long Apple and Google. We'll see if the car manufacturers can fight back. Then the dark horse in this is will Lyft and Uber need to own that experience, right? They

will definitely need to own part of it, because if you get into a Lyft or Uber self-driving car, there will be bits of the interface that they need to control, right? They need to offer you a button that says, “Start the ride.” They need to offer you a button that says, “Hey, emergency. Stop the ride,” that type of thing. They'll definitely need part of that interface. The question is do they need to expand from that point and own the entertainment experience, or will they see that to Apple?

One of the fun things that's happened in the industry is Toyota has been one of the longtime fighters of Android Auto and Apple CarPlay. They've stubbornly stuck to their own systems for a long time. Just this year they finally, or one of the last holdouts to say, “You know what? We give up. We have our own infotainment system, but you can also now order CarPlay as an option in the latest Toyota car.” One of the last standouts to fall, because look, they've eventually given up.

[0:25:47.0] JM: You mentioned the fleet operators, the Uber and Lyfts of the world and wondering about the sustainability of their moat, because today they have a moat because they have this large aggregation of supply and demand of users. As we've seen, the switching cost from one fleet provider to another is not super high. It's not like switching your smartphone. Do you have a sense of the size of the moat that the current fleet operators have from a Tesla, or a Waymo, somebody who could come up with a fleet system, as well as the full stack of car software and hardware?

[0:26:34.3] FC: Yeah, I think one way to think about this size of the moat is to ask the question, if we wanted to fund from scratch, a company to take on Lyft and Uber, how much money would they have to raise? Which is how much money until I knew where people wanted to go, I could recruit all the drivers, I could get enough cars on the road to mount a credible alternative. Remember one of the chief criteria for a picking Lyft versus Uber right now is how long do I have to wait?

You need enough liquidity in a market to actually make that competitive. If you think about that, the answer is its order of magnitude billions of dollars to raise, to go start a startup, to go attack Lyft and Uber where they have strengths now. If you think about all of the auto incumbents who are now thinking about, either owning and operating their own fleets, or selling exclusively to the

fleet operators as an increasing portion of the pie of cars they sell, that's a pretty daunting task to get going. Why is that?

One, the existing fleets know exactly where people want to go, from where, at what point in time, right? Think of it as block by block, minute by minute. In every city that they operate, they know exactly where people are coming and going. Now if you know that, you know what type of car you're going to need, you now know where to put your recharging stations, you now know where you need a certain amount of density, you now know how much you can shift your car to delivering packages rather than people, because you don't need as many cars on the road delivering people anymore.

All of that data is a pretty significant moat. If you thought about starting a startup, you don't know the answers to any of those questions, right? You just got to get out, amass the data and that's a super expensive proposition. I think over time, the moat becomes that data set of where are people going, when, for how long, and trying to start a company from scratch today to compete, that's pretty hard.

[0:28:41.0] JM: I agree with you there. When you think about Waymo, Lyft is on top of Google Maps. Google ends up get all of that data regardless. They also have the data around pedestrian activity and just more granular mapping data. It seems like the long-term moat is in favor of Waymo. I mean, this might be a nonsense argument to make, because this is assuming there is some winner-take-all effect here, when there could just be a variety – I'm sure there's going to be a variety of competition there. If it is a data question, it just seems like Waymo is going to have a huge edge. Unless, there's fungibility to that data set.

[0:29:25.8] FC: Yeah, so the data question brings up a really interesting set of issues. Google definitely has Google Maps data, right? They know partly where people are going, but mostly by driving their own cars, which is a different dynamic than the on-demand part of it. Slightly different data set. The other thing is Waymo maps, the maps that the Waymo cars use are actually not Google Maps.

They are these much higher fidelity, some people call them HD maps, because Google Maps are for people, whereas self-driving cars need – the self-driving algorithms need maps that are

good for them. What's in an HD map that's not in a Google map, that's meant for you using your smartphone? Well, a good example is where are the curbs, right? You as a Google Map user, you don't need to do that, because you can tell where the curbs are, you can see them. If you're a self-driving car though, you absolutely need to know where the curbs are,, because you've got to plot a safe path to traverse.

That's one example of many, many examples where the maps that we use as humans are different than the maps that the self-driving algorithms use. They're actually two distinct sets and it's given rise to actually startups. We funded one of these startups, called Deep Maps, which is creating and maintaining these high-resolution maps that the algorithms need to safely drive around cities. If it were the case that you could just reuse Google Maps, you're right, Waymo would be in a world where they're just significantly in advantage, but it turns out you need a whole different set of maps.

[0:31:02.6] JM: We'd look at Tesla and we can see what a fully integrated hardware and software car design looks like. I thought it was interesting, you drew the competitive landscape between Apple and Google. Is there a framing where we can put Tesla somewhere on that gradient between Apple and Google? Or maybe that's just not like – from the current smartphone paradigm, when we look at the current smartphone paradigm, you have open versus closed, Google versus Apple. Is there any framing you have for what Tesla does personality-wise in terms of its hardware-software integration?

[0:31:44.7] FC: Yeah. I guess, I would say Apple – Tesla is most like Apple in this case, which is an integrated hardware-software company that wants to sell great premium, high-end, high-margin consumer products, right? Exactly the same as Apple, which is they love to sell iPhones, Tesla loves to sell the Model SX3, etc. They're relatively high-margin vehicles, because they are for premium buyers.

Now a open question is will Tesla be a fleet operator itself over time, or will it sell the fleet operators? I don't know the answer to that question. If they transition to being a fleet operator, then obviously your customer relationship with them is very different. It's not I'm buying a Tesla car, I'm consuming transportation as a service by the Tesla fleet. You're right. These are the big battlegrounds, which is every software startup that's trying to sell to the auto manufacturers,

longs to be the Microsoft of this space, which is for every $50,000 car you sell, I'd love to get $5,000 worth of software license value out of that thing.

I don't know if we're going to get back to a world in which there is this dominant software manufacturer that powers the self-driving brains of every car. So far, it looks like the big companies have placed their own bets and they want to vertically integrate in exactly the same way that Apple and Tesla have. GM bought cruise, Ford has this investment in a company called Argo, Toyota looks it's doing it itself through the Toyota Research Institute, so on and so forth. It looks like, they're signs that the biggest manufacturers are going to vertically integrate. Now there may be a set of manufacturers who can't afford to do that themselves, so they might have to go license it, right? If you think of a company like Mazda who makes awesome cars, but it's relatively – margins relative to the big guys, maybe they can afford to make the transition to electric and then build their own self-driving stack and then buy their own, operate their own fleet. They just don't have enough capital to support that, and so maybe there's a set of manufacturers who end up having to license it.

Then obviously they're hoping that the ecosystem plays out more like, maybe Android, where they don't have to pay a company a huge licensing fee. There's a very interesting open source effort in China sponsored by Baidu called Apollo, which very explicitly is trying to be the Android of self-driving, which is high. This is free software and please use it and we're going to try to lift the ecosystem together to defend ourselves against the vertically integrated companies like Apple and Tesla.

[0:34:26.3] JM: In this fray, you have the incumbent car companies that have existing supply chain infrastructure. They know how to make cars. Is that a moat?

[0:34:36.4] FC: I think it is a moat. I think it's harder to make a car, which is bending sheet metal and dealing with labor unions and getting to the continuous improvement in quality that you need to go through. All of those learnings, a hundred years of learnings of bending sheet metal and making very reliable cars is a moat.

Now parts of that moat will become less relevant. If you think about a car today, one of the most magical pieces of technology of all time is the internal combustion engine. It's amazing, it works

as well as it does, which is you have this car with the tank of extremely flammable fluid in it. A couple thousand times, I need to ignite that fluid with just the right amount of oxygen to make the piston go. By the way, I need to do that in snow and ice, and by the way, I need to do that over a 15-year lifetime of a car being driven 250 thousand miles an hour, or 250 thousand miles over its life. I mean, it's amazing beautiful technology.

Now, the bad news is that moat will crumble, because as we shift to electric, we don't need that expertise anymore. Parts of the moat will remain extremely durable. How do I make a reliable car? By the way, the life cycles of these cars are expected to go much longer. If you had a gas-powered car that went 250,000 miles, you were really happy. People would ask you, “Well, what kind of Toyota do you have that gone that far?”

The electric cars are expected to last 500,000 to maybe a million miles, because there are just many fewer moving pieces, like order of magnitude. We're talking about thousands of moving parts, high temperatures, to dozens of moving parts. When we get to there, the electric cars ought to last a million miles. You'll build new expertise, like who has a moat that knows how to build a car that lasts a million miles? I think we're going to see innovations that we don't see today, which is they're going to be much more modular, there'll be parts of the car that get replaced over time and that'll be normal, because fleet operators, that's no problem, they do that to planes today, right?

One of the most awesome things to do is to watch a Boeing 747, I guess that's not a good example anymore, because they retired all that. By Boeing 737 get refurbished, right? They go to these massive hangars and they completely pull the plane apart and they completely add new pieces to it. It's amazing. That's going to happen to our cars, because the fleet operators will have an economic incentive to do it.

I think the incumbent manufacturers should come back to the original question. They do have a lot of advantages, this know how. They're going to have to learn a lot of new things, which is what's it mean to build a million-mile car, not a 250,000 mile car. Then some of their moats will crumble. It's awesome that BMW builds these awesome internal combustion engine vehicles. Too bad, you don't need internal combustion engines anymore.

[SPONSOR MESSAGE]

[0:37:30.4] JM: GoCD is a continuous delivery tool created by ThoughtWorks. It's open source and free to use and GoCD has all the features you need for continuous delivery. Model your deployment pipelines without installing any plugins. Use the value stream map to visualize your end-to-end workflow. If you use Kubernetes, GoCD is a natural fit to add continuous delivery to your project.

With GoCD running on Kubernetes, you define your build workflow and let GoCD provision and scale your infrastructure on the fly. GoCD agents use Kubernetes to scale as needed. Check out gocd.org/sedaily and learn about how you can get started. GoCD was built with the learnings of the ThoughtWorks engineering team, who have talked about building the product in previous episodes of Software Engineering Daily, and it's great to see the continued progress on GoCD with the new Kubernetes integrations.

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[INTERVIEW CONTINUED]

[0:38:52.4] JM: Speaking of which, your focus in one of these presentations around autonomy is that energy infrastructure changes dramatically in this world, because the energy that gets us from point A to point B, our transportation energy is mostly petroleum. Petroleum will shift to electric. How fast could that petroleum-based shift to electric occur?

[0:39:19.3] FC: Yeah, so the estimates on how fast we shift to a post-petroleum world are all over the map. If you are OPEC, you are basically long petroleum. If you looked at the history since the beginning of petroleum, what you see is one of these very rare durable up into the right charts, which is every year we use a little more petroleum. Now there have been a few hiccups along the way. In our lifetime, the Great Recession was a big – was a mild hiccup. There was a recession in the mid-80s, it was a mild hiccup.

If you zoomed out far enough, you saw this unrelenting up into the right, more petroleum is being consumed every year compared to the year before. If you're OPEC, you see that continuing in. The macro trends you look at is more people are living in urban centers, there's a rising middle-class, more and more people will want cars and they just see up into the right. If you ask OPEC, it's basically, “Look, we're never going to reach petroleum. At least, not on our watch, right? Not in our lifetimes and probably not in the lifetimes of our children.”

Now if you ask somebody like Tony Seba, who runs a think tank called RethinkX. He's saying that we're going to see peak petroleum demand in the next five to 10 years as electric cars really take off, right? The most expensive part of a electric car is the battery pack and those prices are shooting down. We have fewer moving parts, so they're going to be more reliable. We're going to see fleet operations, because these cars are going to last a million miles, and the economics as we mentioned at the top will get to be such that it's cheaper to be driven around. All of these things, say peak petroleum, I don’t know, 2020, right? Ten years from now.

The estimates are all over the map, but I think look, that the big secular trend that is impossible to avoid is there will be more electric-powered cars on the roads. They're more reliable, etc. There will be fewer gas burning cars. Now the question is when?

[0:41:19.0] JM: Also, how we get the batteries is a big question. These cars require batteries. Battery production requires a variety of chemicals. There's a limiting reagent there in terms of cobalt. The largest reserves of cobalt are unfortunately in the Congo, which you discuss in your series. In the Congo there are tens of thousands of children who are working in the cobalt mines, unfortunately. Are there any ethical solutions to acquiring that necessary cobalt for battery production? Are there any other limiting reagents to the battery production problem?

[0:41:57.3] FC: Yeah. Lithium and cobalt are the top two with existing battery chemistries minerals that we will need. As you point out a lot of these cobalt, especially are in regions where we're not sure they're being ethically sourced. As the big auto manufacturers go out and lock up supplies. By the way, Volkswagen just placed a 48 billion dollar order for batteries. That is a lot of batteries. They're trying to make sure that the contract stipulate there's no child labor and they're going to try to do as much ethical sourcing as possible.

The throw eight of the big incumbents placing big battery orders will determine how ethically source of the big companies placing these big orders demand ethical sourcing, then we'll get ethical sourcing. It's up to the incumbents to make sure that when they're placing these big orders, they do so in a way that stipulates, “Hey, look. I don't have child labor involved in harvesting my cobalt.”

[0:42:53.1] JM: Did that ever happen with smartphone production? Did smartphone production get ethical over the years, or has it gotten less ethical?

[0:42:59.5] FC: It's a good question. I don't know the answer to that question. Super interesting, but I don't know.

[0:43:05.6] JM: One of the things I thought was interesting that you explored. This is tying back to the urban planning side of things is it these fleets of autonomous cards need places to charge. They need a place to go for repairs, and at the same time you've got lots of real estate that's already devoted to housing cars. You've got these car dealerships, you've got gas stations, there are car rental places that are probably going to be obsolesced by this process. How will the existing real estate that's devoted to cars, how will it change to accommodate the new ecosystem?

[0:43:40.0] FC: Yeah, so the way I think about that is think about a typical city. Then you're right, there are these networks of existing places that will no longer leave. In increasing order of how many of them there are in a given city, there's the DMVs, there's the car dealerships, there's the auto repair places, there's the oil change places, sort of jiffy lubes, right? You can imagine any one of those places being the depots that the fleets go to recharge, to receive refurbishment, right? New tires, or new battery packs.

There's also another fun thing, which is look, if there's no human driver, we have the problem that I like to call the Coke can in the back of the car problem. Which is even well-intentioned passengers might forget to retrieve their Starbucks cup, or their Coke can and they leave it in the back. Now obviously, you as a passenger don't want that. Where do they go to get the Coke can removed, right?

Basically, everybody is playing a massive game of Sim City right now to figure out exactly where to put those depots. You can imagine, we're going to reharvest all the jiffy lubes. You can also imagine that we won't need that many and we're going to just use the DMV space. Waymo has already signed a deal with AutoNation as an experiment for where these fleets get serviced.

[0:45:00.9] JM: AutoNation being a huge chain of car dealerships, right?

[0:45:05.6] FC: Yeah, exactly. Publicly traded company, they own a bunch of auto dealerships. Maybe that's where we go. I don't think we know exactly the answer yet, but everybody's doing the simulations now. This is by the way one of the advantages, if you know where all the cars need to be at any moment in the day. Figuring out where Coke can removal service belongs is one of your advantages.

[0:45:29.0] JM: I just thought that Waymo deal with AutoNation was so fascinating, because there's going to be these strange alliances, that if you try to look at a historical precedent for alliances between technology companies, it's hard to imagine the historical precedent for Google partnering with AutoNation there. It's just an interesting data point.

[0:45:49.8] FC: Yeah, it's awesome. The new partners that will get created out of this as everybody jockeys for a position, right? You've got the automakers who need to think about becoming fleet operators, or at least maybe 90% of their sales go to fleets. Where do we remove the Coke cans? Where do we put the chargers? All of this is going to be fascinating as it plays out. It's going to play out in real-time. This is 10, 20, 30 years as opposed to 50 to 100 a years away.

[0:46:19.0] JM: The big player that we haven't discussed much is the insurance companies. You envision this other second-order effect, where since you have fewer people dying on the roads, the premiums go down, that's one effect. Also, the premiums shift hands. Insurance premiums, instead of being sold to consumers will likely be sold to fleet operators. How do the economics of a car insurance provider change in this new world?

[0:46:50.1] FC: The biggest shift will be that insurance goes from being a B2C, business to consumer business, to becoming a B2B business. Maybe that's an interim stage, so well I'll get

back to that. First, today the auto insurer spend a lot of money advertising to make sure you buy their insurance, right? There are fictional characters you know pretty well. There's a gecko you know by name. There's a woman named Flo that you know, because we saturate bomb the advertising landscape to make you want to buy insurance from Flo.

When we shift to fleets, you don't need to buy insurance anymore, because that'll be the responsibility of Lyft and Uber. Most of it will shift from being B2C, to B2B, and so we don't need to advertise anymore, right? You don't need to know Flo and trust Flo for your insurance, because that's Lyft's problem. Big shift is B2C and B2B.

Then the question to ask is does it stop there? Or will the fleet's self-insure? At some point, they will probably decide not to pay premiums to all state, or whoever is the insurer. They'll take those premiums, keep it in a fund, and then if a car gets into an accident, they can pay out of their own pockets, right? The question being, why would I leave a profit pool available to another company when I can just do it more efficiently myself?

It's the exact same thing that most large employers do when they self-insure their own employee-base, right? Instead of paying premiums to some other company, they basically pocket those premiums and pay health claims out of that pool, right? Every big company does this and the self-insured pools. There's no reason to believe that Lyft and Uber wouldn't do this. We go from B2C to B2B, and maybe that doesn't last very long the B2B thing, because maybe Lyft and Uber and DD just self-insure. That means an enormous pool of money, we're talking trillions of dollars of auto insurance premiums shift hands quickly.

[0:48:46.8] JM: What are the downstream effects of that insurance market changing?

[0:48:52.5] FC: We will see the collapse of B22 auto insurance companies, right? They need to either retool themselves as B2B, or they'll just have to find other lines of insurance, right? Your home needs to be insured still, thankfully for them. Then the big question is how long an interim period between most insurance premiums being B2B to how long until that profitable basically disappears altogether, because the fleet operator self-insure? My guess is the interim period doesn't last that long. There's just no economic reason for a profit pool to exist when the fleet operators drive most of your miles and they can self-insure.

[0:49:32.4] JM: The changes to the justice system are another area of your exploration. What are the new rules of the road that will need to develop within the justice system?

[0:49:43.6] FC: Obviously, the big one is around liability, which is when accidents occur, who is at fault and how do we actually make sure that we can hold that entity responsible? Just looking at the hierarchy, maybe we think the fleet operator is responsible, because they're operating the fleet.

On the other hand, we might think the manufacturer of the car that the fleet operator uses might be responsible. Maybe it's GM providing to Lyft a car, maybe they're responsible. Maybe it's the software owner of the self-driving algorithms. Let's imagine a world for instance where there is a startup that prevails and it's licensed to a car manufacturer, this piece of software that makes the car go around and maybe they're responsible. This is going to be one of the hotly legislated questions, which is who is responsible?

[0:50:36.9] JM: The big question that you ask them towards in this presentation is how far away is this future? There are a range of predictions. Why is there such a wide range of predictions and what is the one that you would weight the most, that you project?

[0:50:54.2] FC: Yeah, there's a wide range of projections. I think the biggest question mark right now is when will cars be ready to drive themselves? I think on the transition to electric, we're already seeing all the motions, right? 48 billion dollars' worth of batteries, right? That thing is just coming and we have a pretty high-precision view of in the next 10 to 20 years, we're going to shift mostly from gas to electric.

The big question mark is when will the cars be ready to drive themselves? One of the interesting things is I meet with startups all the time and I also meet with the incumbents in the space. One of the things that I've learned is that the deeper you are in it and the longer that you've been building the software, the more pessimistic you are about when the cars will be ready. If you're a startup and it's four people, a PowerPoint and your dog, and that's the company, you think it's probably five years away, because you're full of optimism and deep learning is awesome and you've seen some really good results from your early prototypes, you're just so excited.

Then if you talk to Waymo or some of the old timers in this space and you ask them, they're much more circumspect. They won't tell you exactly when it is. Keep in mind, Waymo is operating cars in Mountainville, I was just in one the other day, and in Arizona. They're racking up real-world and simulated miles and they're far, far ahead of everybody, and they're very circumspect about when this happens. Because the deeper you are in it, the more cognizant you are of all the hard problems that remain to be solved. That's the big question, which is is that five, 10, 15 years away? I think that's probably the range, but that's the big unknown at this point.

[0:52:35.8] JM: I think the other perverse thing is that the people who are the most deep in it who are doing the lower-level engineering are often not the ones who are talking to the press, or making these kinds of models, or projections, so it becomes – it's almost like there's a selection for people who are going to be overly optimistic, or who will have a less fine-grained perspective on it speculating on these range of predictions. You end up getting a public perception that is perhaps more optimistic than is the reality.

[0:53:07.0] FC: Yeah. Look, if you're an engineer embedded in the system and you're looking at the bug reports day in and day out, that's a lens through which you look at the world, right? Which is, boy that's a lot. That's a big bug backlog, right, as they say. Yeah, you're naturally more pessimistic, because you're thinking about, well what what's the rate, velocity at which we're fixing these bugs? It's just like any other software development project. Things are complicated, there's lots of bugs.

One of the analogies I'd use for your audience is that, so the big question is do we need more breakthroughs in algorithms? Do we need another big thing, like deep learning to get where we want to go? Or are we just basically a finite number, a big number, but a finite number of bug fixes away? Look, every software engineer knows that when you're building something like a database, or a file system, the initial algorithms are important, right? How you lay out the bits on disk, how good your query optimizer is, how long until we get to consistency over time? All of those algorithms that determine the answers to those questions are important.

Equally important are the million bug fixes in weird edge conditions, right? You had to raise condition between this thing and this thing and then like, I lost power right in the middle. Then do we recover gracefully from that or not? I call that the million bug fix problem. The big question, I think from a software engineering point of view is are we on the path now where it's basically just a million bug fixes, where we just need to encounter more weird edge conditions? Or will we need more algorithm breakthroughs, or sensor breakthroughs or something more fundamental? I think that's the big question that will determine the – look, are we five years away, or 10 years away, or 15 years away?

[0:54:45.3] JM: All right, last question. Much of this conversation is centered around autonomy as it's framed in the consumer, road, pedestrian world, where there are so many problems to solve for for the autonomous vehicle. These breakthroughs in autonomy also affect robots that can harvest your food, or pack your Amazon boxes, or spread pesticides in a more controlled fashion. Autonomy is going to come faster to these controlled environments like farms and oil rigs and factories. It's going to come much faster than the public roads, where you have human drivers and pedestrians, and all these other things. What are going to be the outcomes of those more incremental controlled environments where autonomy comes to and how fast will those come to us?

[0:55:35.1] FC: Yeah, I think that's a great observation, which is that in these controlled environments, like a farm field, or inside a distribution center, or inside a retirement community, we can make so many simplifying assumptions. We have an investment in a company called Voyage, which spun out of Udacity and they're operating a self-driving service in retirement communities; first in San Jose, and then they're expanding to Florida.

Retirement communities are awesome. They are controlled environments. We can pre-map the entire environment. Oh, by the way, nobody goes fast in a retirement community. Awesome, right? Max speed 25 miles an hour. The simplifying assumptions you can make from a software engineering point of view are many, and I think we're going to get to very good reliability very quickly in these controlled environments.

It's ironic that the thing that a lot of the company is committed to was the very hardest problem that we have to solve, which is level-5 mobility, right? Self-driving in any circumstance. Waymo

got out ahead of the pack and everybody followed suit and that's where all the media attention goes to. I think you're right, a lot of these more controlled environments we're going to see a lot of autonomy. As consumers, it's going to be awesome, right? You'll go to visit your mom in the retirement community and she can get around anywhere and you don't have to worry about her having a license anymore.

Or the cost of strawberries follow falls, because we have robotic harvesters and then we have the self-driving trucks that bring them to the redistribution center, and then we have the self-driving shopping carts that cart it to your house. All of those things will happen and the incremental cost of growing something, harvesting something, distributing something falls to near zero and that's going to be an awesome world, in which you can just think strawberry and the drone flies it to your self-driving car and here you are eating strawberries.

[0:57:29.6] JM: Frank Chen, thanks for coming on Software Engineering Daily. It's been really great talking to you.

[0:57:33.1] FC: It was great. It was fun talking and thanks for having me.

[END OF INTERVIEW]

[0:57:39.1] JM: If you are building a product for software engineers, or you are hiring software engineers, Software Engineering Daily is accepting sponsorships for 2018. Send me an e-mail jeff@softwareengineeringdaily.com if you're interested.

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