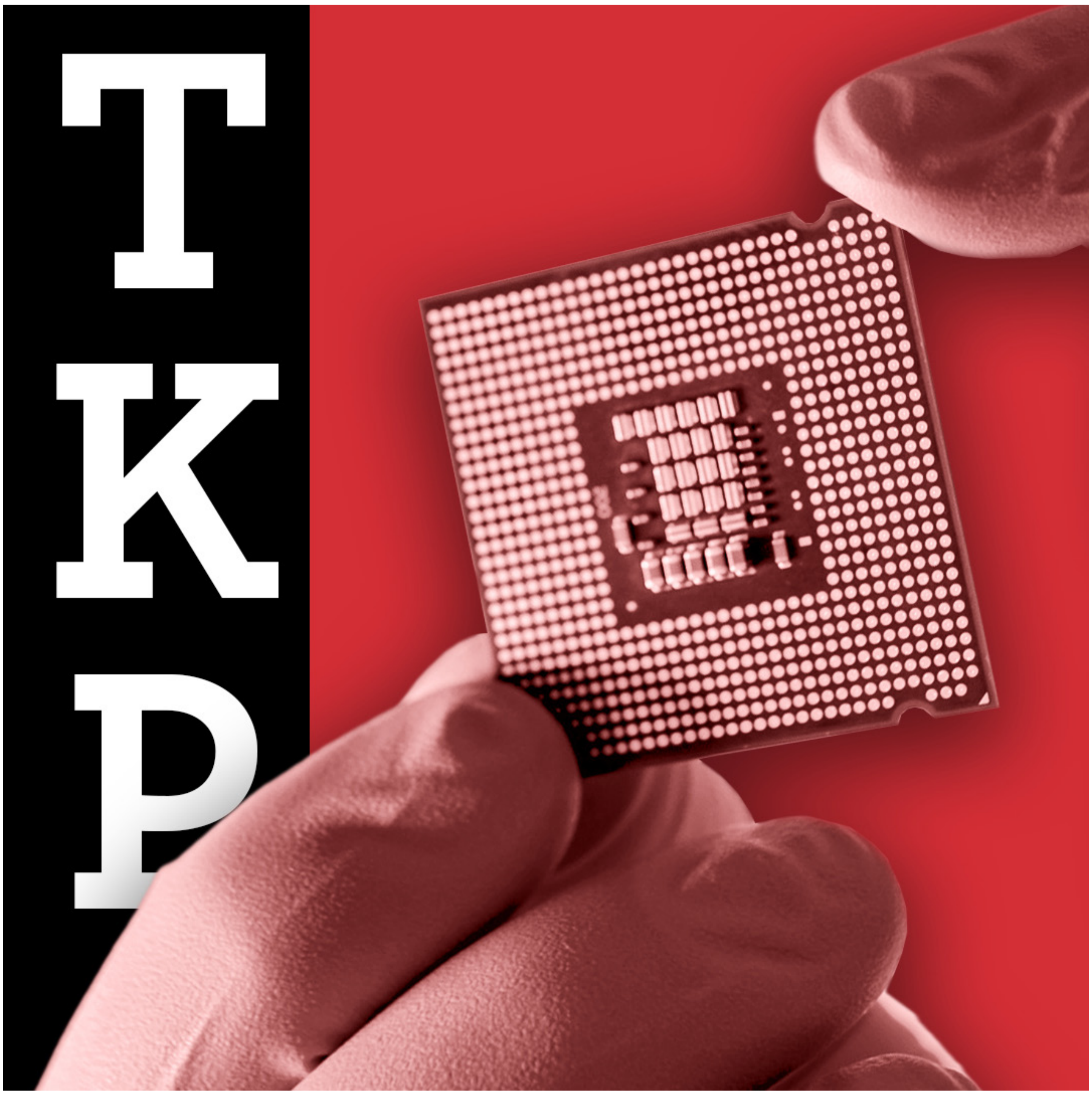
THE KNOWLEDGE PROJECT
SPECIAL EDITION

The Ultimate Bargaining Chip



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If the nuclear bomb was somehow able to trace every tendril of the company throughout the world and just blow it up, would it matter? Most companies you say not really. CVS gets blown up, I’ll go to Walgreens. If Facebook gets blown up, I’ll communicate some other way, right? If a couple of companies in the semiconductor value chain get blown up, the whole world goes backwards 10 years, 20 years, I don’t know, a long way. There’s really only a few companies that can do this.

Welcome to a special edition of The Knowledge Project. This episode is all about semiconductors, their key role in society and the future’s dependency on them. Investors at NZS Capital and experts in the global technology industry, Jon Bathgate and Brinton Johns explain the major players in the semiconductor world, what’s important, how things work, the complications of geopolitics and much more.

Shane: Brinton and Jon, so glad to talk to you guys today.

Brinton Johns: Thanks Shane. Thanks for having us on. We're really excited.

Jon Bathgate: Likewise. Thanks for having us.

Shane: So we're going to talk semiconductors today, and this is such a big concept. It's hard to wrap your mind around. I think the best starting point is going back to the beginning and the origins of the semiconductor and then almost working our way up to now.

Brinton: Yeah. It's a fascinating topic. It really isn't that well understood by lots of folks these days. But of course, the semiconductor came out of pure science from Bell Labs back when AT&T did pure science, when we had companies in the US that did pure science and really morphed and changed the world over time, but more certainly changed lots of companies. It created Intel, created Texas Instruments, created really the modern electronics movement. So there's been a lot of moving pieces. A lot of the foundations have been in the US but certainly it's moved global over time.

Shane: That's awesome. So where do we start? What's the entry point into this vector here?

Brinton: Jon, you want to give it a go and I'll tag on?

Jon: Sure. I guess the way we think about it when we talk about a lot is that semiconductors are really the building blocks for the digital economy. What that means is you can kind of look around the world and I think there are pockets of our lives and pockets of the economy there have pretty clearly already been impacted by technology and by semis like we're all living on Zoom and working on the cloud these days, but also spending eight hours a day on our phones. Then you go around the rest of the economy and think about the next car you buy, that decision will likely be somewhat impacted by semi-conductors. Is it electric vehicle? Does it have some level of autonomous driving or active safety or lane departure detection, things like that.

Think about how drugs will be delivered in the future and even how drugs are discovered, think about right now living in COVID times that we actually mapped the COVID 19 genome, I think faster than any other germ that I'm aware of.

It was mapped in January before COVID even really hit the US. So when we think about it just from a strategic perspective, semis are going into everything. If you think about all the really most exciting trends over the next kind of 10 to 15 years, whether it's like I said, automotive or artificial intelligence or kind of the connected factory and internet of things, semis kind of support all of that. So we feel like semiconductors are the unsung hero of the technology sector that everyone gets excited about software. We all kind of know that software is eating the world a nd I think that that's fair, but the underlying support layer of that really is semis and that's why we're excited about it.

Shane: It's like a key strategic resource for everybody, but there's only a couple of people that can actually fab these days, isn't there?

Brinton: Yeah, that's right. If we think about back to the question, how did we get here? Right. It's a fascinating story. We won't go through all of it here, but if you think about a company like Texas Instruments, which was one of the first semiconductor makers along with Intel and Fairchild, they really used to do everything soup to nuts. They made their own equipment, they had their own factory to make the chips, they of course sold and marketed of the chips and they even sometimes sold and marketed their end device. I mean, we still have Texas Instruments calculators and they did the speak and spell back in the day.

So they made radios, they did everything. Over time, of course more entrants entered the market, the industry matured quite a bit and then we really went to this horizontal model. So there are equipment makers that only make equipment to fab chips. There are companies that build the chips. There are of course other companies that build the end device like Apple or Tesla. Now it's sort of coming full circle where Apple is making some of their own chips and Tesla is making their own chips.

Shane: But when you say making, do you mean fabbing or do you mean making in a different way?

Brinton: Yeah, no, I do mean fabbing. So okay. When Texas Instruments was making their own chips, they had a very promising CEO candidate named Morris Chang.

Morris turns out was passed over for the CEO spot and decided to take a bow out of the industry for a while. He went back to his home in Taiwan. Taiwan said, "Hey, get us into semiconductors." And he said, "You don't have anything here. It's really hard to build chips and you're on an island that has a lot of earthquakes. I don't know what to do." So what he realized from talking to customers is that actually fabbing a chip is the pain point. It's really expensive. It's really difficult even back then, and there are only a few companies that are all that good at it.

So he said, "Okay, well, what if we made a business that we just made other people's chips? We didn't compete with anybody. We just actually fabbed their chips." So to answer your question Shane, when I say Apple and Tesla are fabbing their own chips, to be more precise, TSMC is fabbing chips for Apple. In the case of Tesla, Samsung in Austin is fabbing that Tesla chip. So Morris really created this new business which we call the foundry model.

Shane: So walk me through the value chain there. So if like Apple's designing the chip, somebody on a different architecture, so you have an architecture, you have the Apple engineers designing the chip and you have TSM or Samsung fabbing the chip at the end of the day, and then Apple integrating it into their hardware product through Foxconn. Where's the value add in that? Where's the strategic sort of nature of that going? Why aren't these companies vertically integrated? Why are there so few people that can fab? I mean, I have so many questions.

Brinton: Those are all good ones.

Jon: Yeah. I can start with that. So I guess to start out thinking about the chip design process overall, so if you're a semiconductor engineer at Apple and they have thousands of them now, which in itself is incredible, you design and lay out the chip on EDA software, electronic design automation software, from really only two companies provide this now. It's Synopsis and Cadence Design Systems. And so that in itself, this kind of CAD software ecosystem they've created is already a really robust part of the overall value stack.

If you're thinking about Apple designing a five nanometer chip that's going to be the next iPhone or even in the new MacBook, the precision with which they're doing that is phenomenal. Apple will design the chip on EDA software and then TSMC, Taiwan semi is really the main manufacturer in the world for leading edge semiconductors.

So if you're an EDA company like Cadence or Synopsis, you actually collaborate really closely with Apple but also with TSMC who's the end manufacturer to make sure that you can actually build this design that Apple has laid out, because at the end of the day, you're really kind of bending the laws of physics.

If you're thinking about Apple designing a five nanometer chip that's going to be the next iPhone or even in the new MacBook, the precision with which they're doing that is phenomenal. Apple will design the chip on EDA software and then TSMC, Taiwan semi is really the main manufacturer in the world for leading edge semiconductors. Samsung is kind of the second source, but in terms of really bleeding edge digital chips that you would buy from an Apple or an Nvidia or someone like that, that's all done at TSMC. Then the other part of the value chain is the equipment part of the value chain. So TSMC buys equipment from really a small handful of strategic suppliers, which would be ASML, which is in the Netherlands, Lam Research and KLA Tencor and Applied Materials in the US and then Tokyo Electron in Japan.

So one of the things that's amazing about just the overall kind of like value stack in semi-conductors is there's a lot of margin throughout the whole value chain. And that's really to your question Shane is because, I mean, the industry has evolved over 40 years for this more horizontal model because it really is just really difficult to do the whole thing.

I mean, like Intel used to do their own internal EDA software and they ended up just going and outsourcing it more to Cadence and Synopsis because it really is just like so fricking hard every two years if you're following Moore's law to do every part of the value stack yourself. You kind of see that with the software, with the equipment guys, with TSMC, between the manufacturing and with the chip designer itself. Then the important part that I kind of hit on is there is this ecosystem dynamic where they all collaborate very, very closely. And so there's kind of just this iterative process that's really unfolded over 40 years that has created a lot of really well positioned companies in various parts of the value stack.

Shane: But being so complicated, it's hard to compete. Like how would you compete with a TSM today? How would you build a foundry as a manufacturer? How much capital would that take?

Are we moving to a world where it's going to be more competitive or less competitive, or are the, I guess the rich getting richer in this case where the more chips TSM makes, the more they're going to make in the future, the bigger their advantage gets over others? And then I want to talk about the geopolitical sort of like globalization risks of all of this.

Brinton: Yeah. One of the questions we ask ourselves quite a bit is if this company got hit by a nuclear bomb, would it matter? If the nuclear bomb was somehow able to trace every tendril of the company throughout the world and just blow it up, would it matter? Most companies you say not really. CVS gets blown up, I'll go to Walgreens. If Starbucks gets blown up, I go to Pete's. If Facebook gets blown up, I'll communicate some other way, right? If a couple of companies in the semiconductor value chain that Jon was talking about get blown up, the whole world goes backwards 10 years, 20 years, I don't know, a long way. There's really only a few companies that can do this.

And to your point, Shane, it's not a matter of throwing money at it. Technically, it is extremely difficult. These are some of the most complex machines humans have ever built. They're virtually impossible to reverse engineer. And in the case of something like photolithography which allows Moore's law to go ahead, there's only one company that builds the next generation machine that is keeping Moore's law track. It's ASML in the Netherlands.

So there are a handful of companies that have become, because of this long history of consolidation combined with the non-linear pace of complexity, extremely important in the world.

Jon: And to answer Shane's question on how you compete with TSMC. There's also, I mean, there is like a real world example of this where AMD actually used to own fabs the way that Intel still does, and actually spun out their fabs into an external foundry, into a company called GlobalFoundries and this was probably 2009 or 2010. And they were owned by middle eastern sovereign wealth money. So they basically had unlimited resources to go out and compete with TSMC and try to replicate their model. About two years ago, they were a little bit behind TSMC and they were trying to migrate down to the next process technology now, which at that point was 10 nanometer and they threw up their hands and they literally just said, "This is too complicated and the capital investment and the technology, the lift is just too heavy.

So we're just going to hang back here and make a lot of money and actually doing older technology."

Jon: But it's just, it really is like a case study real time of building the ecosystem and migrating that, down that technology roadmap every two years was just such a treadmill. So to your question, I think at least from TSMC's perspective, the rich do get richer and then Samsung can kind of linger as a second source also.

Shane: Isn't China building a competitor to TSM and Samsung?

Brinton: Yeah. They they've been working on this for a long time, over 20 years, it's called SMIC is the fab that's Chinese-based. Of course, with the recent tariffs on what we are allowed to ship China both from the US side and also from our allies even in the Netherlands, that has set them back quite a bit. They've literally spent tens of billions of dollars on this and they remain around decade behind.

Shane: Why can't they just do what they always do and sort of reverse engineer or steal the technology?

Jon: Yeah. I mean, it's a good question. I mean, for now what they're actually trying to do like their kind of roadmap for SMIC is they're trying to build a factory with no US equipment, because I think they have to at least face the reality that there's a scenario where China does not get their hands on US semiconductor manufacturing equipment for the next decade. So what do you do? Their roadmap for that for now is they're trying to build a 20 nanometer manufacturing line, which is actually about in the next three years. By the time they actually have that up and running, it will be 10 year old technology and this is in an industry where technology is scaling exponentially.

So what they have to do really is, I mean, they have to re-engineer all the process technology that TSMC has built, which has taken decades to build with very tight collaboration with their customers like with an Apple or an Nvidia or an AMD on packaging technology, how you stitch everything together, what's the easiest way to get it from software actually onto the chip. How do you actually build chips that actually have high yields so that customers don't have defects and can actually ship them? Then China has to try to replicate all of the manufacturing technology in terms of equipment, which is also I think probably a 20 year project in terms of replicating the various kind of parts of the manufacturing value chain and Brinton mentioned ASML, which literally has a monopoly on photolithography, which is probably one of the most kind of complex processes that humankind has ever engineered. I mean, it literally is more difficult than putting a man on the moon or building a 747 or you kind of pick what.

Shane: Can you walk me through that? And what makes it difficult? Walk me through, what is lithography?

Brinton: There's a couple of things to understand and I have to get a little bit of technical, but I'll try not to get too technical. Lithography is when you shine a beam of light at the silicon wafer, and therefore you harden parts of the silicon wafers so then you can go back and etch or kind of scratch out the lines between it. And so when you think of a transistor, transistor is a source, a gate and a drain, and you want to put these transistors as close as possible in the silicon wafer, right? So you have to etch these lines in between them.

Shane: And that's what we think of as nanometer, right? Like seven nanometer, five nanometer.

Brinton: Yeah. So the most leading edge chips these days are five nanometer chips and a nanometer in Silicon is about two to three atoms of Silicon. So we're talking extremely small. Five nanometers, less than 15 atoms of Silicon divide the lines. So there is a problem, a wavelength of traditional light is 193 nanometers, but we're making chips at five nanometers. How do we do that? Well, we've had all sorts of tricks that we've done over the past decade and a half or so. We shoot it through a lens that shrinks the wavelength of light. We shoot it through water. It's called immersion lithography, and also shrinks the wavelength of light. But at around 10 nanometers, it became very clear we had to change the light source to something that was a smaller wavelength. And the answer that everyone came to, primarily enabled by ASML is something called extreme light or EUV. EUV is 10 and a half nanometers. Did I get that right? Jon 10 and a half, right?

Jon: I think so.

Shane: So normal light starts at 170 and-

Brinton: 193.

Shane: 193. And then the extreme ultraviolet starts at 10 and a half. Okay.

Brinton: Exactly. Yeah. So to create extreme ultraviolet light, now this is the part that blows your mind. You need to drop molten tin and hit it with a laser. You need to perfectly pulse those, right? So the molten tin is coming down, you hit it at the exact point of time with a laser that explodes it into a plasma, which creates extreme ultraviolet light. Now that sounds hard, right? It's in a vacuum, so it's not too hard. But then you think, okay, well, how often do I need to do that to create a bright enough source to then reflect off of a bunch of different mirrors and finally go down on the chip? Well, it turns out the number is about 50,000 times a second that you need to get that right. And it has to be exact, precise every time. But extreme ultraviolet light is the wavelength is so small that it's absorbed by all known mirrors.

So it doesn't reflect, but you have to bounce that off about 20 mirrors in the machine plus or minus. I may be getting this a little bit wrong, but I'm overall right. Then still have enough impact when it gets to the Silicon to be able to do its job, to harden that Silicon. So ASML had to create mirrors to be able to bounce it. That was a brand new science experiment.

They created those, they had to create the laser that was powerful enough to do that. There's only one company in the world that makes that laser. It's private company in Germany. So this is mind-blowingly hard. I mean, Jon said something the other day. It was like, "It's the equivalent of shooting an arrow from the earth and hitting an Apple on the moon." It really is that hard. It's just ridiculously, like they should win two or three Nobel prizes hard.

Jon: And it's another example of actually their competitor just dropping out. I mean, for a long time, they were two companies in the lithography market. There was ASML and Nikon. Again, at the beginning of last decade, Nikon just threw their hands up and said, "We just don't have the capital and expertise and like willpower to pursue EUV." They didn't even attempt it. And so that's why ASML is kind this natural monopoly. They're actually now the most valuable company or tech company in Europe. So I think it's a little bit discovered, but what they do is it's just kind of like unprecedented. And another amazing fact about EUV systems is it takes four 747s packed full of equipment just to transport one EUV system. And they cost right now they cost about $200 million and that will actually go up to about 300 million over the next like four or five years. Just the engineering lift to Brinton's point on what they created is just like a crowning achievement of humankind in our kind of geeky opinions.

Shane: What's the runway on the extreme ultraviolet? Like regular light gave us up until 10 nanometers I think. What's the runway on the extreme? Can we go three? Can we do two or do we need a new source? Does somebody like ASML just get displaced by a new, better technology or do they innovate on this?

Jon: Yeah, so they actually have given their roadmap through kind of like the middle of this decade at least. They have a new tool called high numerical aperture lithography which Brinton can give the equation that has numerical aperture for the line width. But basically that's the tool that'll be 300 million. So that gets you towards the end of this decade. So I think when we get down to like, it'll be two or one and a half nanometers or something like that exiting the decade, I do think that'll be time for the industry to start thinking about, I mean, they're different device structures or different materials and things like that. But the ecosystem is so tightly collaborating on all this.

I think even if it's not exactly the generation after a high and a high numerical aperture EUV, like ASML will play some sort of a role in advancing Moore's law just because first of all, they're putting billions of dollars of R&D into it, along with Intel and TSMC and the whole ecosystem. But also there's only so many companies that have the scale and the kind of expertise and the internal knowledge from how these things are built to kind of be the company that will drive us on Moore's law from here.

Shane: Talk to me about Moore's law. So just give listeners an idea of what it is and then talk about why it's proven so difficult to maintain and then what's the trajectory here? Are we butting up against it? Is there a five-year visibility where we're not going to hit it? At some point we reach one nanometer, do we go smaller than that? Is that even possible, physically possible? Walk me through your thinking on this.

Brinton: Well yeah, it's a great question. There's a lot of, we don't know answers to when we get to the logical conclusion of that question. Moore's law was created by Gordon Moore who worked at Intel. Back in the sixties, I believe he wrote an article. He said, "Hey, we think we can double the transistor density about every 12 months." He didn't revise that a few years later to say probably like every 12 to 24 months.

So every two years, what it means is for the same price, you get double the numbers of transistors on a piece of Silicon. That's enabled semiconductors to push into every last vestige of our lives. 60 years ago or 50 years ago, it wouldn't have been possible. They would have been way too expensive. But because we get double the amount every two years for free and the manufacturers get to keep equivalent profit margins at those rates, then it's been semiconductors have become democratized.

They've become into everything. Of course, that's what a lot of the stuff we talk about all the time is really all about AI, it's about high functioning, leading edge semiconductors, internet of things, it's about cheap, lower end semiconductors, 5G. We could kind of go down the list, machine learning, autonomous driving, these are all enabled by semiconductors. As Jon said at the beginning, software gets a lot of attention, but really semiconductors do the work.

Shane: And it's harder than software.

Brinton: It's way harder. Yeah. It's extremely difficult. So what happens over time with the Moore's law, we don't know. Like Jon said, we see a runway to the end of the decade. We, meaning collectively humankind. I'm not an engineer, I just play one on TV. But it could mean that we change the substrate. So maybe it's not Silicon, maybe it's something else where we can jam more lines in a smaller space, because the atoms are actually smaller. So maybe it's changing the substrate, maybe it's changing the way we do architecture, like Jon said. Then there's like a host of other things that go into it. So TSMC recently gave an update and their chief scientist had about five things that they think will allow them to keep on Moore's law through the end of the decade. Also combining chips into what are called chiplets, stacking chips on top of each other and on the bare metal and then other things.

So we spent a lot of time on photolithography, but there are a lot of other key things. Like for example, we are now building transistors higher. We're stacking them into what are called 3D transistors. And there's one company essentially that enables that, Lam Research. The design rules for doing these are extremely hard, getting harder. As Jon said, that's Cadence and Synopsis. There's only two companies in the world that allow you. If you're an engineer that's designing chips, that's your Excel. That's what you go in and you live in every day.

So we don't know how Moore's law will continue. There are a bunch of different options that we may go to in a decade, but this is not really a new problem either.

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Shane: In fairness, we've never really known how it continues. It just does through innovation, right? Like in hindsight, it's easy to say, well, this is why it continued, but at the time looking forward, you get maybe one to two years and then you're-

Brinton: Yeah. I mean, with EUV when Jon and I started looking at this space, I don't don't know, let's call it 2005. People were talking about EUV and it was like, oh yeah, well, if we can figure out how to get a laser bright enough. And if we can get that 50,000 times a second to fire precisely. And if we can create a mirror to bounce that stuff around, it was a lot of ifs and it was like, wow, this is not a done deal by any means. We did it as a species, but it was really difficult.

Jon: I guess what I'd add on the Moore's law piece is there's kind of like two different ways to think about Moore's law. There's kind of like the Gordon Moore definition of doubling transistor density every two years. And that actually, I think has kind of empirically ended. I think like the industry cannot actually scale that way anymore just because we really are bumping up against the laws of physics that Brinton was talking about with like the number of atoms you're even looking at. But then there's really this idea of can we just double computing capacity every two years or computing performance every two years? And I still, I think with the broader efforts of the whole ecosystem, Brinton mentioned TSMC has kind of five different efforts around the edges of computing with those. And that's actually called like more than Moore, it's kind of a cheeky pun in the semi industry.

What can we do outside of Moore's law to keep driving performance? And those I think will continue to drive us down. At least the theoretical Moore's law of like are we getting more economic value from every process, no transition. And then we're also adopting new architectures like GPU's or specialized chips for the data center or for the edge. You're seeing companies like Google and Amazon do their own Silicon with that in mind. It's not just all about kind of like Intel brute forcing ourself down Moore's law. It's really about everyone in the whole ecosystem being more serious about designing specialized chips for various applications.

Shane: Talk to me a little bit about those competing architectures. What are the competing architectures, who are the key players and what are the sort of different strategies that each architecture enables and sort of gives you an advantage in?

Jon: Sure. I can start and Brinton can jump in. So X86 is kind of the workhorse architecture of the industry for a long time. That's kind of the core Intel architecture that has built the PC industry and a lot of the cloud, like a lot of server chips are just built on the Intel X86 architecture. And really the only relevant companies there anymore are AMD and Intel. The other architecture that really came into ... became really visible with the rise of the smartphone as the ARM architecture and ARM had a different business where they invented and refined the architecture that rather than building their own chips, they actually licensed the technology. And so they grant licenses to companies like a Qualcomm or an Apple to build processors that would power a smartphone. And so what ARM did amazingly well is low power, like in the middle of the two thousands, everything was an Intel X86 processor and everything had to be like plugged into the wall and have two fans.

We didn't really think about this world of low power and that's really what ARM facilitated. Then more recently what we've seen is the rise of the GPU. That's really kind of been Nvidia's stronghold. AMD also has a GPU product. So those are processors that really started for gaming and kind of rendering images. Then what we discovered in 2014 and 2015 is GPU's are just amazingly well-suited for especially honestly, as Moore's law and Moore's law's cousin is Dennard scaling kind of slowed down that as compute power was slowing, you can actually put a few GPUs next to a CPU and speed up a workload with incredible success in that. That kind of actually is what started this whole explosion in artificial intelligence that we've seen over the last five years. It's kind of the rise of the GPU.

that's mostly really been enabled by Nvidia. They've taken their data center business from a couple of hundred million dollars to a $4 billion business over five years doing that. The last one that we think is really interesting is actually RISC-V, which is an open-source competitor it's really to ARM, I would say. That is much earlier in its life cycle, but it's getting a lot of traction especially.

Nvidia is actually acquiring ARM right now, which has had this whole suite of issues given ARM needs to kind of feel like Switzerland since they work well with Qualcomm or Apple or some of Nvidia's competitors. That's kind of an interesting proposition for them to be owned by Nvidia, but RISC-V is an open source architecture that's kind of just now starting to get traction that we're watching closely.

Shane: Brinton, do you want to add to that?

Brinton: Yeah. Well, if you think about a CPU as like a big V8 engine, right? It takes a lot of gas, but man, it's fun. It gets to places fast. It's a work horse and that's what Intel created and that's really what computing power is done on the back of today. GPU's are very good at ridiculously parallel problems. So things like rendering images on a screen, which is a parallel problem. I'm going to do line one through 1080, over and over. I'm going to refresh that ever faster. So if we think about CPUs as a big V8, GPU would be like lots of little electric engines or just lots of little bitty engines doing a parallel processing and then putting it back together at the end.

It turns out that's really hard to do. And there were a bunch of companies trying to do it back in the day. When Jensen started Nvidia, there was around a hundred competitors. Now there's only two, it's just AMD and Nvidia. That is also very hard to manufacture and those are both done at TSMC. GPUs have enabled artificial intelligence. It doesn't work without massive GPU clusters.

Shane: Are Nvidia and AMD neck and neck in that, or is one the clear winner because it strikes me that Nvidia could invest a lot more money into that technology than AMD.

Brinton: Yeah, that's right. Nvidia actually was really primarily Jensen who's one of our semiconductor founder heroes, was incredibly strategic about this probably starting around 15 years ago now where they introduced a software program called CUDA, which was open. Anyone can use it and it allowed people to write code to GPU architectures. It's much easier to write code to one CPU that's going to process it in what's called serially and then dump it out, dump your work out at the end, but it's much more difficult to write code to take that same process, break it apart 500 times and then have something put back together at the bottom. That's what CUDA does. CUDA enabled GPUs to go into the data center.

So for a long time, when you owned Nvidia as an investor, you thought, okay, are they going to get the next PS4? How big is that cycle going to be? It was really about gaming. But when they went into the data center, the game really changed.

Shane: Keep going.

Brinton: Okay. So it's changed to such an extent that they are now worth multiples of Intel. So you think about GPUs for a long period of time, Intel was really sort of the largest maker. I mean, they wrote the architecture for the PC, right? Basically if you wanted crappy graphics, you can just stay with Intel processor. But if you were a gamer, then you wanted that Nvidia or AMD GPU in your PC and Intel sort of begrudgingly let all the work interface with that. But with this shift, the GPU actually becomes more important in many cases than the CPU. That is a massive, massive change.

Jon: I guess I'll interrupt you really quick, Brinton. But one of the things that we're seeing in AI that is just like incredible is these big AI models that get written about every few months. They kind of follow their own Moore's law where AI model has like different parameters or different weights. That's roughly kind of like the synopsis and the brain that you're trying to replicate. And the number of parameters per model in AI is doubling every three or four months right now. So if you think about that over five years, we literally, it's like an 800X improvement in computing power that you've needed to pull off to keep up with just the way these models are growing.

I think the most recent one literally has like 65 billion parameters, that's the GPT three model that came out of open AI. GPUs have really been like what's facilitated that. And so the computing throughput that's needed to maintain pace with these models is just unbelievable in that that's why Nvidia has just been so well positioned is they've been right there with the computing power and the software stack to facilitate them.

Brinton: Yeah. And it's of course, even though Moore's law is slowing down and as Jon told me the other day, it's like, "Hey, look, even the company that created Moore's law can't keep pace with Moore's law, Intel." It doesn't feel that way so much with AI because of all these other things we're seeing.

Shane: So I want to go back to something you said, which is the GPU is more important than the CPU. Can you expand on that?

Brinton: Sure. It's just taking more workloads than the CPUs take. I mean, look, this is early days, still the massive majority of the work being done in data centers is done by the CPU.

Increasingly, it's looking that the GPU will play a more important role in the future. I don't know, Jon, would you have anything to add?

Jon: Yeah, I guess what I'd add is just that if you think about like how you actually train, like the class example everyone always uses, if you want to train a model to like recognize what's a cat and what's not a cat and you just force feed one of these models millions of photos of cats and not cats and labeled data. To do that, you basically need a cluster of GPUs with only a handful of CPUs. And that the CPU really is like kind of just operating in the background, while the GPUs are really where the data is kind of being forced fed basically.

That's why, I mean, at least for certain applications, they're plenty of applications that will just run on CPU because like, if you're hosting your email or something, it just is not that complex of a computing problem, but anything that really needs intelligence added to it I think over time, you're seeing more of the compute being put into GPU or even other architectures and kind of being pulled out the CPU. We think that's kind of Jensen's ultimate goal at Nvidia to be honest is to marginalize the role of the Intel CPU, which is also one of his big competitors and really push the GPU into the forefront.

Shane: Intel seems like a dead man walking here. Didn't they just give up fabbing? They seem like they're all over the place. They're a mess, they're falling behind like so far behind. Am I wrong?

Brinton: It's been tough. I mean, look and Intel is still an amazing company with lots of great engineers. It's been tough for them. It does seem that they've lost their way in many ways. They haven't given up fabbing. They haven't really decided exactly what they're going to do, but they did talk about outsourcing to someone like TSMC really. It could only be TSMC, and the future, which after they said that, I said at a team meeting, that's something like having your evangelical pastor come into the church and saying, "We don't believe in God anymore." I mean, I just can't imagine what that's like at Intel whose religion is we build better transistors than anyone else in the world.

So we don't know exactly what it's going to look like, but it has been tough times, both from a fabbing perspective as it gets increasingly difficult and from just the way the architecture and the data center and everywhere else is moving.

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ASML, which literally has a monopoly on photolithography, which is probably one of the most kind of complex processes that humankind has ever engineered. I mean, it literally is more difficult than putting a man on the moon or building a 747 or you kind of pick what.

Jon: And it really is a good example of just like how hard this stuff is that Brinton kind of mentioned that Intel invented Moore’s law and they’ve been a company that really, I would say for the last of like the 45 years we’ve been talking about Moore’s law, for 40 of them, Intel was the leader of Moore’s law and they were the one that advanced us down Moore’s law down each sequential node on this like phenomenally tight schedule. Then around 2015 or so, they really just fell off. And instead of taking two years to hit the next process technology note, it took them five and they’re still honestly trying to get there. So to the question on how come China can’t re-engineer all this, well, if Intel has doing this forever and has basically unlimited resources, and honestly it’s an existential crisis for them to not be the leader of Moore’s law, if they can’t do it, I kind of would bet against anyone else in the world being able to do it outside of maybe TSMC or Samsung, because they have also been doing this for 30 plus years.

Shane: Is this a race where if you fall behind, you’re basically out of the race no matter what happens at this point, or can you leap frog a generation of technology? Because it sounds to me as I’m listening to you guys, this is so complicated. It’s so complex. If you fall behind even a generation, it becomes exponentially harder to catch up and then to push forward.

Brinton: I guess we could put it this way. No one’s ever done it before. I think you’re right. It’s a nonlinear problem and when you fall behind it, it goes exponentially, time goes exponentially against you. To skip nodes, just so to say, I’m going to skip five. I’m going to go straight from seven to three is almost impossible because you run into so many manufacturing problems. A lot of times they’re specific to the type of part you’re manufacturing.

Someone asked me the other day, "Well, you know, China has lots of money. Why can't they just like, if they could technically in a different administration, get access to ASML and Lam and applied materials and KLA Tencor. If they get access to all these machines, why couldn't they just get the company engineers in there, put it together and start building chips?"

It's just so hard that when you get one plus one plus one, you could get like blue and you're like, where did blue come from? I have no idea where blue ... and it takes you a year to trace where blue came from just so you could change it to get four. So to answer your question, it seems incredibly difficult. You would have to say the odds are heavily against them.

Jon: And that certainly is their ambition there. They're trying to kind of pull in like I said, their last process technology migration was five years. They're trying to shrink that to two years, but they even kind of had to confess over the summer that that two year timeline had slipped on their seven nanometer process. And so it's just so hard to kind of make that leap frog step, but I mean, they're also one of the best technology companies of all time, so we have to give them a little bit of a chance of potentially closing it. We'll see.

Brinton: And they're incredibly strategic for the US and the US wants to see them succeed.

Shane: Okay. So let's talk a little bit about the geopolitical factors here. Semiconductors are key to the information age. We have a long runway where we know that they're going to be super important, they're in everything. I think, the new iPhone has like a billion transistors or something on their chip. What is going on with the trade war and what's the role of semiconductors within that? What's the role of semiconductors within the trade war? Why is it such a strategic asset? And in some ways, has world war three started and it's just over like semiconductors and we don't know it?

Jon: We worry about that. I guess there are a few things. I mean, this really tipped off, I would say three years ago. ZTE, which is kind of like the, it's kind of like the Motorola of China. They make smart phones and wireless equipment and it's a big company, but it's not a national champion or anything.

We actually cut them off from semi-conductors because they were selling phones actually to Iran or equipment to Iran and that violated sanctions that the US had imposed. So we cut them off. We put them on the entity list from the department of commerce and cut them off from semis for a few months and it basically like crippled the company. It's like they can't build anything. The issue with the way the semi industry is composed now is a lot of the really strategic Silicon is coming out of the US.

I mean, I think half of overall semiconductor revenue really is from US companies and China consumes over half of semis.

Jon: At least they'll buy them and re-export them, but most chips are actually bought by a Chinese company at some point along the value chain, but they can't design or build anything there. So anyway, we saw that ZTE was basically crippled with their inability to get chips. Then Huawei saw that and they actually realized they need to have a plan for if they get cut off from Silicon and sure enough a year later, and I think it was probably May of 2018 or so, Huawei was put on the entity list and Huawei is kind of the Cisco and Apple of China. It's like they're the leading smartphone vendor. They're playing a huge role in 5G, both in China and globally. If they can't get chips from key players like a Qualcomm for their smartphones or from someone like Broadcom for their wireless base stations and enterprise equipment, they literally can't build this stuff.

So I think the administration in the US pretty quickly realized that chips were kind of this like ultimate bargaining chip, because if we want to cripple some of the most important companies in China, and especially like these companies that are really facilitating 5G and AI and some of the most important technology trends over the next 10, 15 years, this is like a chess piece that we can use basically. So that's kind of how the shot across the bow was fired with ZTE and then escalating it to Huawei. And we've really tried to clamp down on Huawei now. We basically have said, Huawei actually just at one point it was about 20% of TSMC sales, and they're almost as big as Apple to TSMC.

I mean that's just like the scale of Huawei, which is amazing to me. The US basically has told TSMC they can't even build chips for Huawei using US equipment and by the way, you can't build anything without US equipment.

So we've just totally crippled kind of what was three or four years ago, a national champion with over a hundred billion dollars in revenue. And we have other levers that we can pull. I mean, if China can't build their own Chips and we're not going to give them equipment or let TSMC build it for them, then how do they roll out 5G? How do they keep up with AI especially in China where surveillance and using facial recognition and a lot of vision processing technologies are used. They have to have access to leading edge technology. And so that's why it's become this crazy pawn and this whole geopolitical game that we've been playing over the last few years.

Brinton: Yeah. We have no comment on the current administration, but somebody there certainly understands how to hit leverage points and they've hit every one of them with extreme precision. If you were going to try to cripple an adversary, this is the way you would do it. You would go after these specific companies. So it's amazing how effective their tactics have been.

Jon: And then do the other, your kind of joking comment Shane about world war three is most of the critical chips, everyone besides Intel that's building advanced semiconductors in the US is manufacturing them at TSMC. Whether you're Nvidia for AI or high performance computing or doing heavy simulation or I mean, for chips that go into like strike fighters and fighter jets and into defense applications or go into space and things like that, that's all being built in Taiwan right off the coast of China. So that's why it's become such a geopolitical football so is TSMC has just become so strategic and all this, because we really dropped the ball on keeping manufacturing of chips in the US like besides Intel and one Samsung fab, no one really builds leading edge chips in the US. So TSMC is just so strategic and all this and so that's another kind of lever in this whole geopolitical game.

Shane: In your opinion, why doesn't a country like Canada with its vast land and water resources and all of that take this on, more Switzerland than sort of a neutral party, but domestic capability of manufacturing semiconductors? What goes into the policy considerations a bit bringing this back? I saw something about TSM creating a factory in Arizona, I think, but it was only for 20,000. It just seemed like a political puff piece more so than reality. How do we get that technology back into friendly or closer, I would say Taiwan's friendly, but how do we get it back closer to sources that we consider more reliable than ones that are possibly being circled by ships?

Brinton: Yeah, it's really hard and it takes a long time This evolved over 40 years, and it's not like you just break ground in Arizona and start it over. There's a whole ecosystem around TSMC. There's an Alliance of people that work together to do this. So it just, it can happen, but we're talking-

Shane: What are the steps? Like what are the steps to make that happen, to repatriate that technology and then also to create organic domestic capability?

Brinton: Well, it begins with a favorable program to bring those factories back to the US, which it looks like we have with the chips act that has bipartisan support to it. Then over time, you begin to bring those capabilities back. However, our TSMC has such a head start here and such a knowledge base, and it is a national champion of a company. They wouldn't like to bring it all to the US and can we do it without their help? Maybe, but maybe not. We don't know.

Shane: But they're a public company. Couldn't you nationalize them? Couldn't the United States buy them and then repatriate that technology and then relist them? I mean, or is that crazy?

Brinton: Nationalize TSMC?

Shane: Yeah. It's a publicly traded company. They could take it over. Couldn't they?

Brinton: That would be world war three, for sure. So about 70% of all chips either on the front end of the backend, meaning on the manufacturing side on the wafer or the packaging side go through the Island of Taiwan. We're pretty sure it's a sovereign nation. China's pretty sure it's theirs. So it's a problem for the world. It's a huge problem. It's sort of an artifact of history after Morris got passed over for TI. I mean, we never want to build fabs there, but they're all there. All the collaboration is there to bring it back, it's extremely difficult.

Jon: And there's also, there is, I mean, to Brinton's point, there's a whole ecosystem of material suppliers, there is assembly and test, which is kind of the back half of the manufacturing process. I mean, there are like hundreds of companies that are companies you would have never heard of that are a part of this ecosystem. I think it is possible to bring them over, but just to do it efficiently it's just going to take time, time and a lot of capital.

I mean, there's interest in both from a federal level. We have the chips act to Brinton's point, but also, I mean, I would think that TSMC's biggest customers also would like to have a fab here, just so they don't have to, so they can sleep at night, right? I mean, like if they can't launch the next iPhone because TSMC is having issues with Taiwan sovereignty or whatever it is, then that is a big problem. So I think that's another kind of vector is you should get pushed from TSMC's big customers over time.

Shane: It's interesting to me that COVID happened and we're like, "Oh my God, we don't have domestic mask capability to do this," but nobody's thinking about domestic semiconductor capability. So why isn't it like Intel, Apple, why aren't these guys combining together and making their own fabs, even though they're all using different architecture, they're all using sort of like their own engineers to design the chips. Why aren't they making a TSMC competitor?

Brinton: We've wondered the same thing. I mean, one reason is because just TSMC is so wonderful. I mean, they're phenomenal. They're the closest partner in many cases, they love them. They're enabling their products and they're a dream to work with from everyone we've ever talked to about TSMC. So they don't really see a problem, but geopolitically is it problem? Absolutely. So we've asked this question too. I don't know really the answer. Jon, do you ever get speculation?

Jon: Well, I do think that's actually a really good question because I think that's definitely their ambition and there's an open letter from Bob Swan, Intel's CEO that they had ambitions to be more of a player in domestic semi-conductor manufacturing. But the problem is they've never done this model well of being foundry where you're Intel forever has just build Intel chips. On the very, very much on the margin, they've tried to build, kind of be a third-party manufacturer for other companies, but they have just never been able to do it well. And so, I mean, the most visible example is they actually worked with this company Altera, who they then acquired in 2016, but they can never get the manufacturing right and that actually ended up being a really difficult acquisition for them. The other thing is Intel's technology is actually inferior to TSMC's now.

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The US basically has told TSMC they can’t even build chips for Huawei using US equipment and by the way, you can’t build anything without US equipment. And so we’ve just totally crippled kind of what was three or four years ago, a national champion with over a hundred billion dollars in revenue.

So if you’re Apple and you’ve been working with TSMC forever and they’ve got the leading edge technology, it’s a pretty hard move to go back to Intel. So I think maybe if it’s something that is really a national strategic importance in terms of something for aerospace and defense or something that really just have to be built in the US, then you can make that argument. But it just is so hard to replicate the model for Intel, even though if I were Bob Swan, that’s what I would be trying to do. I think it’s such a good question.

Brinton: And the Taiwan government is a major stakeholder and TSMC, so yes, they are public, but it’s not quite as easy just buying them and moving them.

Shane: So who is the guy that did the TSMC, like they funded them and they brought them to Taiwan. They said like, create all this stuff. Who was that? What was the name?

Brinton: Morris Chang.

Shane: Morris Chang. So who’s the Morris Chang that you could do that to in the United States or Canada or Western Europe. There’s got to be somebody who’s on par with that where you could be like, “Here’s a hundred billion, 200 billion, let’s go. It’s going to be a 20 year project, but we got to do it.”

Brinton: We probably have a few that come to mind. Morris turns out was just incredibly special in history, but yeah, there’s a few that come to mind.

Shane: I'm thinking for all the Canadians who listened to this, we need to find somebody to fund.

Jon: That is exactly what China is trying to do. They have hired some senior operational people out of TSMC and thrown crazy numbers at them and probably said this is a 20 year march. You've got, I mean, China has raised these funds multiple, that are tens of billions of dollars. And so they could put 50 billion behind them. Actually, I don't know them by name in terms of who kind of the up and comers were at TSMC that they've been able to pluck out, but it is like all of the, I would say the very best people to build a business like that in China or the US or Canada would be the manufacturing folks from TSMC. Then the only other people, I'm guessing this is what where Brinton went with this is just to take like a visionary that knows the ecosystem really well. Like Lip-Bu Tan is the CEO of Cadence Design Systems who's been one of the leading VCs in semi-conductors actually for decades and runs one of the most important companies in the whole ecosystem and he's on the board of Samsung. He knows everyone.

So someone like that, I think that really probably would get the playbook down and would at least know who to call would be who I would call. I think Brinton might've mentioned Rich Templeton also who's the CEO of Texas Instruments and it's who we think one of the all-time great leaders in semi-conductors, would be the other one that would have a shot at it because TI actually still runs their own manufacturing and so he gets manufacturing. I mean, it's different because it's a lot older and isn't like truly a bleeding edge, but I think he understands the model and at least how you would go about doing it.

Shane: Talk to me a little bit about TI. I mean, I keep hearing their name crop up over and over and not to mention it seems like they're really good at investing shareholder capital.

Brinton: Yeah. They're amazing. There's really two ends of what we're talking about. We've got the leading edge companies, companies that are developing the most advanced chips in the world, that's sort of the Intel, Nvidias of the world. Then you've got the catalog companies, which are sort of the Legos that go around that leading edge chip that make it all work seamlessly with products. Those catalog companies may have tens of thousands of parts.

TI has what we call a catalog company. They've got lots of parts. They take a long time to develop, but once you develop them, turns out they have 30 or 40 year shelf lives. So TI did develop leading edge parts for a long time and like Jon, they manufactured themselves.

It turns out that business that they were in mainly making cell phone chips got really competitive and the margins were rooted out of it. So Rich, Rich Templeton, the CEO of TI made this strategic decision to get out of that business. It turns out it was the majority of their revenues when they decided to get out of it and they couldn't sell it. They tried, but no one wanted to buy it. They actually bled it down to zero and then they doubled down on the catalog business. So to your point about being very good with shareholder capital, these were massive capital decisions and they were incredibly good for TI shareholders.

Jon: So just to add to that, so the beauty of what they do, they're the biggest analog chip company in the world. Like if you think about like, they're basically two different kinds of chips. To Brinton's point, there's digital, which is like zeros and ones, big, thinking in binary big, heavy digital chips from Intel or Nvidia, and those can cost a few thousand dollars and then there's analog chips and analog really communicates with the outside world. So analog chips can measure signals or sound or vibration so it's not just zeros and ones.

It's really interpreting the physical world. The beauty of analog is the average selling price of an analog chip is around 30 cents. So it's like these guys sell like billions and billions and billions of between whatever 10 cents and a few dollars worth of silicon to tens of thousands of companies.

So they really play well in like the industrial market, which has really like 14 different kind of sub markets. That would be heavy equipment or factory automation or building automation or medical devices. Then the automotive market, I mean, cars have tons of analog just because there's a lot of like power management that has to be done, there's a lot of different signals that have to be processed. So TI has really doubled down on these markets that are going to change really slowly over the next like 10 to 20 years, but they're just like playing for duration. Analog semis to what Brinton mentioned also is you kind of win a part in a car model and that's really not going to change the next like 10 to 20 years. And it can go even longer if you went in like a Jon Deere tractor or like a Caterpillar piece of heavy equipment.

So it’s almost like a software model where once you’re in, it’s like a recurring business for 20 years. That’s why, I mean, TI actually has some of the best margins in the S&P 500, and it’s been a phenomenal cash generator and a great stock because they’ve built this business that is just like built on durability and being in these long markets that change very slowly, but they can just monetize and especially as silicon kind of pushes deeper into all of them over time, it’s just a great place to be.

Shane: Are there a lot of natural competitors to TI in that space?

Jon: Yeah, so there are a few. So the analog market is still really fragmented. Analog devices is kind of their natural competitor and they actually just announced two months ago or so that they wanted to acquire the number three player in the space who’s Maxim Integrated. So the beauty of it is I think the combined TI plus the new analog devices after they acquire Maxim will probably be about a third of the analog market. So even though you kind of have these like two 800 pound gorillas, there’s still just like so much market share to go after. I do think it’s one of these markets where the big will get bigger over time, both because you just have more breadth of products, but it’s also like TI’s reach is unmatched.

They actually go direct to their customers now, instead of going through distribution. They have tens of thousands of parts. They can release more new products every year than a lot of their competitors, probably half the market could combine. So there are natural competitors and all the companies have amazing margins. The beauty of like a 30 cent part is you’re not going to go in there and offer 25 cents to like get the business. The customer doesn’t even really care about that that much, because it’s probably a electronic system that has hundreds of dollars of content in it. There are competitors, but it’s not really like one of these like really price driven markets like you might see in the smartphone market or something like that.

Brinton: And it takes forever to introduce a relevant catalog of parts. I mean, TI with all their engineers may introduce 5% new parts per year. So it’s 20 years to get the catalog. So it’s just one of those businesses you can’t come into and make a better widget and then gain a lot of share. It doesn’t work that way.

Shane: I want to try something I've never really done before, but I've never really done something with three people on a podcast. So I want to take the view of, okay, if Jon, you take the view of the United States and I want to hear what you would do. What is this strategy here? We want to bring back domestic capability, maybe it's not. And Brinton, I want you to take China and you play China. And I want to hear you guys just riff on what do you see as, and these are opinions obviously, but give us your opinions on-

Brinton: Little bit of chess.

Shane: Yeah, a little bit of chess here. Give us some back and forth on things.

Jon: I think I probably have the easier one because I think the US is in just such a better starting position. But if I were designing our semiconductor approach for the next decade in the US, I would go to all the major designers, to Apple and Qualcomm and Nvidia and Amazon and Google. And by the way, this is like trillions of dollars of market cap and of economic profit that you could walk up to and just say, "We need to have a consortium to support domestic manufacturing, and the government will support this." But this really is like we have the whole ecosystem here.

We own the equipment. We've got all the design guys here, we've got the software here, what we don't have as manufacturing. So we probably need to put together a hundred billion dollars to spend over the next decade to really bring manufacturing here strategically. Honestly I think that's something that if I were Apple or Nvidia or anyone else I would sign up for, because it's so strategic and they've got the capital to do it, but that's where I would start.

Shane: So you'd limit technological use in China. You would cut off all US products, all US-

Jon: So that's a great question. What I would do is there are technologies in China that they've developed, they're totally legitimate and they've acquired IP that is legitimate. I mean, they're entering into the NAND flash memory market, and that's technology they've built domestically and also acquired like totally above ground.

I just think as in terms of like how we're perceived on the global stage, I don't really think that we can just ban shipments of equipment to companies that actually have legitimate IP. The US hasn't done this, but I would not support anything where the IP is in question. So I think an outright ban is probably not the right way to go. It's just making sure that, I mean, the beauty of the chip business is there are only so many big projects.

You kind of know who they all are and where the IP came from. It's like, there's three or four memory projects in China and two foundry projects. So you kind of know where it came from and if it's legitimate or not. And so if it's not legitimate, then you can cut them off and we've actually done that. There was a DRM project the IP's origin came into question. This was about two years ago now and we stopped selling them equipment and everyone just walked off the project. It was like a $5 billion project and it's now just like an empty factory sitting in China, which is just amazing.

Brinton: Let's say Jon did cut the equipment off to me in China and I wanted to get that equipment back. I think I have two roads open to me. One is of course the piece of equipment I want most is made by a company in the Netherlands. I can try to play nice with them and sway them away from following US policy. So is that diplomatic road open to me? And then there's a much more immediate road, which is, I just say, "Okay, Shenzhen used to be a special economic zone.

I'm going to change a law and I'm going to put locks on all of Apple's factories." Every iPhone is made in China. I could stop that tomorrow. There would be no more shipments coming out of China. So that's my first move if I'm really getting crazy, right?

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I have to believe that the rest of the world is watching. Our ability to really set one of the largest countries in the world, one of the most powerful countries in the world back 10 or 15 years should be shocking, shocking for everyone. That one set of companies, one handful of companies really holds the power to do that.

Then the second move is I move to take Taiwan either through diplomacy, which doesn't seem to be working at all because my government got ousted in the last election, or by force. The third move is I can say, "Well, I make precursors to a lot of your drugs. You can't make those drugs without what I make in my country. Those are now no longer available to you." So we as China, when I say we, the Chinese government, because that's what I am, we have leverage points like you do, maybe not high technology leverage points, but in the supply chain, we have massive leverage points too, and we can cut those off and that can cause you a lot of pain in the short term. I can't imagine how Apple, how Tim Cook is sleeping at night knowing all of his factories are in China and we're kicking an ant hole there.

Shane: Jon, how would you respond to that?

Jon: Yeah, I mean, I think this basically is how it turns into a big game of chicken, right? I mean, it really is like, who can keep a straight face before we clash into each other. If I were Tim Cook, what I'd be thinking about is, I do think that Apple is one of the few examples of China allowing a foreign company to come in and flourish. And I do think like on a 20 year horizon, China wants to have it be able to hold examples like that up to the world. I don't think they want to be a completely closed off economy and that I think that can change. But I think that it's kind of if you're playing chicken, I would say, "Okay, go ahead and shut that down.

And by the way, I've got some manufacturing in Vietnam and I might miss an iPhone cycle, but in two years, I'd probably spin up 80% of my manufacturing capacity in Vietnam and the rest in Mexico." I do think there are other parts that are a little bit more pinned into a corner, honestly like rare earth material. Yeah, rare earth materials is another one. That's kind of how I would take it from Tim Cook's perspective.

Shane: Any final thoughts Brinton on that?

Brinton: You know it gets really ugly, really fast. And really it comes down to, what do you want to do with Taiwan?

Of course, if China has moved to take Taiwan, they would have TSMC, but we still wouldn't. It's not like we'd be shipping equipment over there anymore. So they still have some somewhat of the same problems. So could they take that through diplomatic means? I don't know. But it just gets really ugly, really fast.

For us, it's sort of crazy because China is a country we've been going to for 20 years. I've never thought of them in these terms. I've always thought of them more as a partner. Do they do dodgy things? Absolutely. But does everybody sort of sign up for it to get access to their markets? Absolutely. They know what's going on, but they want access to the Chinese consumer. So they allow it. But the sort of the head that we've seen this come to in the past four years is not something I expected.

Shane: That was really fun. I liked that. Thank you guys for indulging me in this little back and forth here and hypotheticals, but what are the sort of most constrained rare earth materials that go into the manufacturing process?

Brinton: I don't know the answer to that. Jon, do you?

Jon: No, I'm not an expert. I just know the percentage of rare earth materials that go into some key technologies including smartphones, it's like 90% comes out of China. And I do think like in terms of the list of the levers they can pull, that one's up there. I think we just have to be mindful and I think we focus a lot on what we have that's strategic that they really need, but they have some of that stuff too.

Shane: I mean, it's great when we can sort of like have this no one can sort of pull the cord on anybody else because we're symbiotic and we're mutually dependent, but if you don't have that mutual dependence, all of these sort of like globalization actually breaks down really quickly in escalation or hostility, right? If there's no mutual dependence or no mutually assured destruction, then there's all of these other considerations that go into it. I think maybe we are at that level of mutually assured destruction without weapons here just from a trade perspective.

But when you start looking at all the things that are sort of outsourced that are critical infrastructure, masks, antibiotics, semiconductors, and you start looking at things through a different lens, it becomes a lot more apparent that some of these things you want to have domestic or at least guaranteed friendly allies who are controlling it, right? There's a big difference between China doing antibiotics and Canada doing antibiotics from the US point of view, right? The same as probably Western Europe and I think that that's just a really interesting and fascinating lens to look at things through.

Brinton: It's eyeopening. It's very eyeopening and I have to believe that the rest of the world is watching. Our ability to really set one of the largest countries in the world, one of the most powerful countries in the world back 10 or 15 years should be shocking, shocking for everyone. That one set of companies, one handful of companies really holds the power to do that.

Jon: And then part of the problem is it has just worked so well for so long. Like the equation for a company like Qualcomm or Nvidia, they don't have to build factories and put an advanced semiconductor fab costs tens of billions of dollars to be able to outsource that and have it conveniently made in Taiwan. I think that's just worked so well until we honestly got to this point and everyone looks around and it's like less than 15% of semi-conductors are built in the US now. So I think that's why we have this, obviously with all the geopolitical tensions also, you just had this realization and that's why, I mean, the industry has really made this hard push tilt to lobby for, with the chips act, more government support to try to bring incentives to build more than my conductors here in the US.

Brinton: Like Jon said, it's a whole ecosystem. I mean, the way it works now is really simple. It's like you do that design, right? You send it over electronically, TSMC fabs it, they ship that chip to Shenzhen, Foxconn put it together. There's a whole host of other equipment makers that are in that same area, which puts it together in the Apple fab. If you're talking about an iPhone for example, or an HP computer or whatever, and then you ship it straight to the US and the company actually never touches it. So it works really well. But to bring that back to the US is just, it takes a whole ecosystem. Those ecosystems move in decades.

Shane: This was a big, hairy topic that we drove into today over the past 75 minutes. Is there anything we missed that you guys want to cover?

Brinton: I think one of the things that Jon has said repeatedly is interesting. I mean, semiconductors of course are fascinating in and of themselves. Of course the geopolitics and how we got to a handful of companies that really control the fate of the world. That's all interesting.

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About 70% of all chips either on the front end of the backend, meaning on the manufacturing side on the wafer or the packaging side go through the Island of Taiwan. We’re pretty sure it’s a sovereign nation. China’s pretty sure it’s theirs. So it’s a problem for the world. It’s a huge problem. It’s sort of an artifact of history after Morris got passed over for TI. I mean, we never want to build fabs there, but they’re all there. All the collaboration is there to bring it back, it’s extremely difficult.

But for a long time, it was really dependent on what came next. Was it the PCs were growing, did the PCs need more DRAM or something like that? Or then this of course the cell phone market came up, which was a massive market that drove semiconductors. Today it’s really different. It’s not like we’re looking to the cell phone market. Jon has this great line that says, the next big thing is there’s no next big thing. Everything’s the next big thing. And Jon, I should just let you say it.

Jon: Yeah. I mean, I think that there is no next big thing basically in the industry and the reason that we maybe going back to the beginning of the conversation about really the history of the industry. It’s always been kind of driven by like one big application. It was like mainframes and then desktops, and then laptops and smartphones and that’s like 40 years of computing basically. Now it’s the future of the car, it’s the future of the data center, it’s industrial equipment having intelligence, it’s medical devices. I think for the first time, there’s not at least to us an obvious kind of like consumer or business application, it’s just going to be the next exciting application.

So I think just like for the durability of the industry, it’s great having a lot of exciting growth drivers at once. And it’s brought a lot of capital and excitement to the industry for the first time in a long time.

Like there are actually startups and semi-conductors for the first time in forever. You're seeing huge companies like Amazon and Google getting into the market for the first time. And so it just shows there's just like a lot of ... it's kind of this renaissance that honestly wouldn't have anticipated 10 years ago, but it's really exciting to follow along.

Shane: Excellent. Thank you guys so much today. This was an awesome conversation and I really enjoyed it.

Brinton: Thanks so much, Shane. It was great.

Jon: Thanks for having us, Shane.

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