Hudson Institute

Virtual Event | Maintaining US Semiconductor Leadership

TRANSCRIPT

- Keyvan Esfarjani, *Senior Vice President and General Manager, Manufacturing and Operations, Intel*
- Mukesh Khare, *Vice President of Hybrid Cloud, IBM Research*
- Jay Lewis, *Partner, Silicon Projects, Microsoft*
- Mira Ricardel, *Principal, The Chertoff Group*
- Thomas J. Duesterberg (Moderator), Senior Fellow, Hudson Institute

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A video of the event is available: https://www.hudson.org/events/1962-virtual-event-maintaining-us-semiconductor-leadership52021

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Hudson seeks to guide public policy makers and global leaders in government and business through a vigorous program of publications, conferences, policy briefings, and recommendations.

Tom Duesterberg:

Okay. Welcome everyone to this conference on maintaining U.S. semiconductor leadership in a rapidly changing world. I'm Tom Duesterberg, senior fellow at the Hudson Institute, and I'm delighted to be joined by a group of experts in both technology and policy concerning these questions. Although the U.S. industry remains the global leader in semiconductors, manufacturing of semiconductors has slowly been shifting outside the U.S. and American chip manufacturers are also facing intense competition from global competitors.

The economic disruptions of the pandemic, and more recently, the severity of the semiconductor shortage for major industries have only served to highlight critical issues facing this industry. Hudson is pleased to welcome such a distinguished panel with both policy experts and cutting edge technologists. Hudson acknowledges the support in recent years from both Intel and Microsoft. So, let me introduce our panelists so we can get into the substance of this conversation.

First, I'd like to introduce Keyvan Esfarjani who's senior vice president and general manager of worldwide manufacturing and operations, including strategic planning at the Intel Corporation. Keyvan has over 25 years of experience with Intel. He has a PhD in engineering from Purdue University. Next, we have Mukesh Khare, vice president of hybrid cloud, IBM Research. Khare also directs research on artificial intelligence and advanced semiconductor technology and AI hardware enablers for IBM. Mukesh has a PhD in engineering from Yale and a master's degree in engineering from the Indian Institute of Technology. We also have Jay Lewis a partner in Silicon projects for Microsoft. Jay leads projects focused on the future of hardware supply chain with a focus on national defense systems. He recently served as deputy director of the Defense Advanced Research Projects Agency or DARPA at the Department of Defense, where he had oversight over micro-electronic systems. Jay has a bachelor's from Georgia Tech and a PhD in engineering from the University of Florida.

Finally in last but not least, we have Mira Ricardel, who is a principal at The Chertoff Group who advises a wide variety of clients for companies like Intel on national security and regulatory policies. She has a distinguished career in government service. Most recently serving as under secretary of commerce for export control at the U.S. Department of Commerce. And she also helped oversee the committee on foreign investment in the United States during the last administration. Mira has previously held positions in the U.S. Senate and the departments of state and defense. She's been educated at Georgetown and the Fletcher School of Law and Diplomacy.

So, let me go straight into questions. We're going to start with Dr. Esfarjani. What do you see as obstacles to manufacturing of semiconductors in the United States, which is a question on the table generally, but more specifically in the United States Senate as we speak? Is it really a talent shortage like the chairman of the TSMC, the Taiwan Semiconductor Manufacturing Corporation, has suggested? Also, could you comment, is it important to have research and development and manufacturing co-located or at least nearby to foster interaction between fundamental research and the actual manufacturing of something as complicated as a semiconductor?

Keyvan Esfarjani:

Tom, thank you for the question. And it's an honor to be here and talking to the Hudson Institute audience. Intel Corporation being in actually one of the pioneers of the semiconductor manufacturing and technologies that goes way back more than five decades, knows this business probably better than anyone. And I would say given the years of our innovation, which this business and this industry really thrives on, we are having a tremendous opportunity for this planet, which is more and more dependent on data. And that data is all foundational element of that is semiconductors is all the chips. So, what has happened since the last 30 years or so is where U.S. being the center of universe when it came into that

foundational technology all that innovation, somewhere between 30 to 40% of the world's supply of manufacturing of the chips, that percentage of that share of the world has dropped significantly to about 10 to 12% now.

And a big reason for that is essentially the uncompetitive environment that we have in the U.S. compared to other locations around the world, and particularly Asia. And that trend is a problem because a company like Intel, which is global to supply semiconductors for the world, when you see that supply chain start to deteriorate from United States to other parts of the world, then the world is becoming more and more dependent on a particular region. And especially when that manufacturing technology is going away, the innovation with that also carries with it and that has a significant consequence. And this is a call to action for not just Intel, but for the world to really make sure that technology and that innovation continues to thrive and to stay in the United States.

And to your question about what are the challenges, because this is such a capital intensive business and it does have a significant multiplier of its economic impact. Having government incentives is one element of making sure that the business continues, the overall industry continues to thrive. That's primary reason as to where those incentives are being offered outside of the United States and that's... Unfortunately, it's a competitive environment and that's drawing a lot of that talent, a lot of that business outside of the United States.

So, first and foremost, is having a very business friendly environment, strong regulatory policies, and coupled with incentives is one big element of this that has to continue be focused on. And we're very encouraged that the U.S. government administration is actually taking this very, very seriously, especially with the recent CHIPS Act. This is all going to be a great starting point.

Another element of that that you've pointed on, which is, it's about talent. It's about pipeline of the high skill talent. Semiconductor manufacturing unlike other manufacturing, it is very, very sophisticated. We are dealing with dimensions that are at the nanometers. We are talking about five, seven, five, two nanometer technologies. And just to the layman's term, this is basically putting billions of transistor on a size of your fingernail. So, linear manufacturing product at that level of precision, at the atomic level, then that requires advanced education, advanced skills. Pushing the limits of science and technology. So, it's absolutely critical also, in addition to incentives, to promote the advancement of STEM education, the pipeline of that talent coming in. So, incentives, talent, strong regulatory environment, all these things are absolutely critical for continuing this journey that Intel started more than five decades ago and we are absolutely continued to be committed as you may know, a lion's share of our investment continues to be here in U.S., and we have high paying jobs that are in the U.S., but really to promote that and continue that, it's more critical than ever before to really focus on those areas and make sure this element of this critical business, which has to stay in U.S., continues to thrive and stay here.

Tom Duesterberg:

Okay, thank you. Perhaps we can return later to the question related to the synergy between the actual manufacturing and the research that goes into this.

Keyvan Esfarjani:

Yep.

Tom Duesterberg:

But let's turn to Mukesh. IBM just made an extremely important announcement that you have perfected the means to produce semiconductors, the two nanometer or nanometer level which is just astounding. I believe that means something like 50 billion transistors on surface of the size of a fingernail, which is

hard to comprehend. Could you tell us a little bit about continuing U.S. leadership and innovation in this design and what were perhaps the most important breakthroughs for IBM to achieve this incredible advance in the speed and capacity of semiconductors?

Mukesh Khare:

Thank you very much, Tom, for your question, and thank you for inviting me to be able to share some of the excitement and some of the breakthrough that is coming out from this work. In fact, today I'm here in Albany, New York, where we have truly, I will say, the world's most advanced facility for collaborative research. And our goal continues to be to drive innovation, drive frontiers of technology forward. And at IBM, we call it the hard tech. We do the hard tech and that's really important. That's really important to IBM's business. And that's very important to the U.S. semiconductor industry and our leadership.

As Keyvan said earlier on, between Intel and IBM, I mean, these companies have essentially created semiconductor industry. It's the Moore's law that everybody's riding on. It's the Dennard scaling that figured out, how do we continue on this journey of Moore's law? And at the end, what's the economic value? How does semiconductor industry continue to provide this economic value or 2X more value every two years? And that's what it is all about. And I completely agree with Keyvan that this technology is at the core. The semiconductor is at the core of the entire acceleration in every part of a business. So, to us, it's extremely important that we continue to drive leadership technology. It's very important that we continue to show the kind of breakthrough that we shared in our announcement of two nanometer technology. In fact, we are very proud that bringing in partners like Intel and like many US companies who work with us together would really accelerate because as Keyvan said, this technology that we're developing, it's not rocket science. It's way beyond rocket science, the way I call it. It's way beyond rocket science.

We're talking about depositing layers of atoms with the precision that, I will say, it's just unimaginable, especially for a manufacturing place like what Keyvan has. Depositing these materials, etching and creating those structures. For a layman's term, again, two nanometers is pretty much the size of a single strand of DNA. That's the type of technology that this industry, we are trying to develop and show to the world that it's possible, and this industry can continue to make progress.

So, we are very excited that we are able to work on this, work with our partners, develop this technology and help U.S. semiconductor industry and U.S. innovation to continue and move forward. It's important for IBM. IBM, fundamentally, is a technology company. At our core, we are a technology company. We are trying to solve difficult problem of digitalization, moving clients to hybrid cloud, enabling AI capability through differentiated technology, and at the heart, the big technology differentiation comes from semiconductor chips. So, it's very important that we continue to invest, continue to drive that technology forward and we are very proud that we could share with the world our two nanometer announcement that we are able to build these devices. We're able to develop the right features, transistors. The transistor that we are sharing, the nanosheet device structure in two nanometer is very unique and we were very proud to be the first one to announce the structure in 2017, and then we continue to perfect it so that we can make it really, really adapted to meet the needs of two nanometer generation.

What it tells us is that the... And I will underscore some of the things that Keyvan said, we have the talent and we have the spirit to drive innovation. We need help. We need support because there is very strong competition out there. And we are a very great supporter of the CHIPS initiative that is being put together by the U.S. government to really reinvigorate this industry, both in the space of manufacturing as Keyvan was saying as well as in the space of R&D because you need very strong R&D at the national level in this high-tech so that it can feed into all the industry that then... Of course, overall manufacturing industry in U.S., but many industry that rides on to semiconductor. As well as talent,

you've touched on that as well. So, all these three aspects of having a strong talent, having a good R&D pipeline, and having a strong manufacturing in the U.S. is super important for U.S. competitiveness as well as for the competitiveness for a company like IBM. So, we are very thrilled with this announcement, with lots of things we talked about, and I'm here to discuss this further with this distinguished panel today.

Tom Duesterberg:

Okay. Thank you, Mukesh. We're going to move on to Jay Lewis at Microsoft. Microsoft is perhaps one of the biggest users of semiconductor technology and is involved in fundamental research that Jay is helping to lead. I'm wondering if you could give us some insight into Microsoft's thinking about next generation data center semiconductors, which enable artificial intelligence applications. Something that I think Mukesh knows a lot about as well. And what needs to happen to promote the production of them in the United States, presenting national policy moves in that direction, which I think clearly it is? Jay.

Jay Lewis:

Yeah. Happy to come on in that first. Let me just repeat that. I appreciate the chance to be here and to talk with you. So, it's a pleasure to be here. The particular topic that you mentioned, artificial intelligence, is a great example, I think of some of the trends, also some of the challenges and maybe some of the risks where policy makers should be paying attention. Just to talk a little bit about the trends, I mean, just looking at what is happening today is very exciting. Microsoft built one of the five largest supercomputers in the world and hosted that on Azure just to support the work that's going on at OpenAI, just to see what extremely large AI models can do. Certainly not alone. There's work going on in Microsoft and Azure cognition and what we call the project Turing program where we developed, I believe, it was a 17 billion parameter model. This was about 10 times larger than the largest model about a year before that. And I believe since then, Google has exceeded a trillion parameters in a model.

So, just looking at this field where it's not just exponential, I mean, it's 10X per year. It's just amazing to watch these incremental steps. So, the scale and complexity are obviously growing tremendously fast and will continue to grow. So, I think because of that, it really highlights some of the interesting needs and trends in the industry. So, there are corollaries to that growth. You'll need to see more specialized Silicon just for AI. There are only a handful of places where very specialized processors have really sort of caught on and made a big impact, and AI has shown to be one of those areas where it's worth making those big investments. So, you see a few companies that are really leading today. Nvidia is one of them, Google has their own hardware, but of course there are a lot of other companies that are planning to compete there. But when you look at U.S. production, I think it's an example of one of the risks and one of the risks of concentration of supply. And that's one of the things that companies like Microsoft really worry about when you have a bottleneck in the supply chain where unexpected events or unexpected challenges can really disrupt the investments that you're making.

So, when you think about AI, in particular. For example, I think discrete GPUs are almost all being made by two companies, Nvidia and AMD. They all come from Taiwan. So, it's sort of a scary risk in terms of potential disruptions there. And even today you're seeing supply challenges in some of these products. So, you have companies like AMD and Nvidia developing these products. They're very performance sensitive, so they need to be made in the most modern technologies available. So, they're competing with Apple and others for capacity at the latest process nodes and they're all coming from one vendor and one location. They're amazing products, but sort of highlights some of the challenges in the industry. And it's a good example of, I think, where supply diversity which is something you think about when you're a consumer of these chips, a buyer of these chips, would really reduce some of these long-

term risks. We've heard about the CHIPS Act already. I think the goals of the CHIPS Act are really, I think, well aligned with trying to diversify where some of these things are made and so if you can think about having these modern fabrication nodes in the U.S. from Intel, from TSMC, from Samsung, from others that I think you're doing a lot to address that problem.

Tom Duesterberg:

Okay, thanks. We'll go back to some of the things that you touched on, but let's ask Mira Ricardel to introduce us a little bit more to some of the national security questions that arise from U.S. technology leadership and the challenges from other major competitors. China is determined to become a player in this field. I don't think they're there yet, but we do have a concentration of fabrication capacity in Taiwan, to a certain extent, Korea. So, what do you think about the state of the semiconductor industry in the United States that raises the most important national security questions? And do you think the administration is on the right track in how it's addressing this situation at the moment? Mira, over to you.

Mira Ricardel:

Thank you. Thank you for letting me join these big brains here on the technology front and talk about the policies that can either help support what they're trying to do or, on the other hand, make it more complicated. I thought maybe we'd have a little scene setter. If we were doing... The United States is in a very different situation than it was maybe 10, 20 years ago when I was in the Pentagon just after 9/11. So much of our focus was on counter-terrorism and on the technologies that could detect things like bio attacks or missile defense, counter IED, stealth. A lot of those were being driven really by the U.S. government, but today the U.S. government is no longer the driver of these advancements in technologies. It's a consumer, not a driver.

And so, this conversation we just had, just demonstrates the fact there's the private sector that's really developing the capabilities, the IP for our advanced technologies and the ones that the Pentagon, in particular, from a national security perspective or intelligence community, really relying on. Things like machine learning and artificial intelligence and all of these have been these leaps of technology that we've just heard some of have been enabled by the advances in chips and semiconductors and not just... We've talked about manufacturing, but it's really the IP development and I think what is happening right now is unlike our focus on counter-terrorism, we have a strategic competitor in China. And so, at the same time that we have this greater competition, we have more reliance on the private sector for advancements in technology.

The U.S. share in the semiconductor industry has gone down just as the importance of it to our country has gone up. And so, we're at an inflection point and we really need policies that are more appropriate to where we are today. There's a lot of debate about industrial policy. I think we need to really think about just the fact that without technology leadership, we can't have economic strength or military capabilities. So, we can't be number one in the world if we don't have technical superiority. And I think China understands the correlation between technology leadership, the economy, and military, which is why they've prioritized investment in the semiconductor industry. There's some estimates about $150 billion they have it made in China, 2025 program.

And so, at the same time, I'm glad to see some of the emphasis on this now, but what has happened in this last 10, 20 years is that so much of the manufacturing and development and advanced IP has been concentrated in South Korea and Taiwan where their governments have heavily subsidized their chip makers. And so, from a national security perspective, we care about supply chains. We need to hedge against disruption. It doesn't matter what the origin of the disruption is. The impact is the same. Whether it's the pandemics or automobiles or its regional instability, which by the way, we find our

allies in Asia or in the midst of a very difficult region. We have to prepare for that. So, we have to, one, be focused on technology leadership from IP to production. We have to be concerned about where we are in things like advanced logic or we're not going to get anywhere in terms of artificial intelligence, which is critical for technological superiority. And we have to make sure that we have a robustness in capacity that is sustainable over time.

Tom Duesterberg:

Okay. Since you brought up the question of China, let me just ask a general question. I mean, there's been a lot of focus on China and China's putting immense amounts of money into building up semiconductor capacity. They do have certain parts of the industry in China. TSMC produces a lot of chips in China. Is Chinese technology, their level of technology, something that at this stage can really be competitive with U.S. and maybe European technology or is that five or 10 years down the road? Keyvan, you want to take a stab at that or...

Keyvan Esfarjani:

Yeah, sure. Sure. Happy to, Tom, but before I do that, if I may just comment on the previous answers. I think the feedback was quite united that having that balanced supply chain given the importance of this foundational technology is hugely important, but I also want to make sure it does not get lost into the details that I think all of the panelists were mentioning, especially from Mukesh and Mira, that the foundational element of this semiconductors is the R&D. And that has to be part of this whole equation. When you hear that, "Hey, I'll just come open up manufacturing here in U.S." If the foundational technology, the know-how is not here, that does not create this supply chain resiliency. It does not give you the overall mitigations that are against national security like Mira was talking about or bringing up the innovation which then feeds into manufacturing that Mukesh talked about. It goes back to the foundation of the Moore's law. It's the innovation and then the innovation feeds the manufacturing.

Now, to your point about China, sure, they have massive infrastructure. They have massive incentives as Mira talked about, but what is right now the challenge or what they don't have is that initial foundational technology, which feeds this industry, which feeds that. And you can argue, is it five years? Is it three years? Is it 10 years? But for leadership products like what Jay was talking about to really drive those advanced computing capabilities, you need to be at the leading edge, at the the five and the two nanometer sort of technology because with that, you can get performance, you can get better power, you can get very, very high computational capability that really matters for companies like Microsoft that was mentioned because of AI applications.

But clearly, the advancement of this without talking about particular country, but this is the... For being in those enabling capabilities, you have to have leadership in technology in those areas. And to date, the companies that are really advancing this are the Intels and, of course, you heard about... Right now, there are others like other companies in Taiwan are being utilized for this capability. And that's sort of where the capability is right now concentrated.

Mira Ricardel:

And if I could just add one point. I agree, it's not just about the money that's been invested whether it be by China. It's about developing the IP and having it here in the U.S. and protecting that IP. And I think there's been a lot of focus by the previous administration and the current administration on protecting that IP because that is the way to keep our technological edge.

Keyvan Esfarjani:

Yeah.

Mukesh Khare:

On the same theme, maybe I can add a little bit more to this is, IP is extremely important to underscore both Keyvan and Mira's comment. And that's why from IBM side, we are very, very careful about creating IP and protecting IP. And IBM has been the leader in U.S. patents for the last 28 years. And the three companies you have here on the call between IBM, Intel and Microsoft, we are the top three companies in the United States. If you look at the top five companies, there are three U.S. companies, and all three of them are represented here on this panel. So, you can imagine how important that IP creation and protection is to our business and to this industry.

Keyvan Esfarjani:

Yep.

Tom Duesterberg:

Okay. Let's perhaps go a little bit more into what's going on in Washington right now. There was a mention of the CHIPS Act, which would provide support for actual building of manufacturing capacity, but there's another bill that's perhaps maybe joined with the CHIPS Act called the Endless Frontier Act, which addresses the larger field of research and the way it was originally proposed by Senator Schumer and Young. Most of it would have gone to the National Science Foundation, but I'd like to know in addition to manufacturing technology, there were other technologies that support the advances in semiconductors. There is a need for new materials, I understand, because their energy we're approaching a point where the systems require so much energy that we probably need new materials and maybe even new technologies like photonics to keep the Moore's law moving forward. We need things like 3D chips, I believe. So, I wonder if you could comment on what some of these other areas are and if this Endless Frontier Act, if you believe that that will continue to support U.S. leadership in the overall ecosystem for the semiconductor industry. Mukesh, would you like to lead off on that one?

Mukesh Khare:

Of course, Tom. First of all, I'm really, really excited that Endless Frontier Act is being proposed. If you look at it, there are three legs of this tool that we want to drive and make progress on. We talked about manufacturing, extremely important. We talked about R&D, very important, and university and talent and workforce. And this entire pipeline, all three of these components, the university, the workforce, the R&D environment, the NSTC that is proposed under CHIPS as well as the manufacturing, all three have to be strengthened to make sure that the semiconductor industry as a whole and U.S., as a country, can continue to make progress and continue to maintain its technological leadership that is desired.

So, clearly, Endless Frontier Act addresses the early part of this pipeline. Manufacturing is the other end. What is coming in? So, I'm very excited that Endless Frontier Act is coming along with or as a part of broader investment. And then some of the technologies that you talked about, Tom, they are really, really at the heart of what can continue to drive the Moore's law that the semiconductor industry forward. Does it demand new material innovation? Absolutely. Look at how many elements of periodic table are used in semiconductor manufacturing. Most of it, it's the materials. How do you use more materials? How do you create... When you're talking about two nanometer chip technology, it's not about just traditional make things smaller. It's about, go at the fundamental material innovation level.

3D chip technology. 3D is so important because we are just running out of room. When you're talking about two nanometer technology generation, which is, as I said, size of a single DNA, there is no more space left in the two-dimension. You have to go three-dimension. And, in fact, there is significant technology leadership in U.S. and we need to continue to drive so that we can start to stack chips or functions on top of each other. So, clearly, you touched upon another very important topic, and then finally, how do you communicate with the space of photonics? Because the speed is increasing so much. Clearly, those are really, really important areas. And I will say doubling down on those fundamental research so that seven to 10 years from now, some of those things will make it to manufacturing is super critical. So, from my side and from IBM side, we are all in and we are trying to shape it and help guide so that at the end, it benefits the country and our U.S. leadership.

Keyvan Esfarjani:

Tom, may I just make a couple more comments on that because Mukesh covered it very, very well. Given that, yes, the foundational technology, the advancement of material science, device physics, those are just fundamentals where you got to push the limits of science and technology at those limits. But I think another element which is critically important, hopefully, for the audience to take away is this is an industry unlike any other where you can have the greatest technology, you can have the greatest innovation in material science, but half of this equation is you got to scale it. You got to take it to high volume manufacturing. You got to be able to do it so that it's not just a science experiment in a lab. This is something that you want to be able to make sure that you bring it into mass markets. And you want to get... You only get one or two tries, and if you pick the wrong sort of road to take here, if you're not so right on your material selection, or if you are not so right in your technology architecture, wow, this race, you're falling behind, and it could take you years to catch up.

This is why it is critically important that foundational technology is very, very on solid grounds. And it has a pipeline of the support, the research projects, the industry working with the researchers, with the leading researchers around the world; universities, governments, DARPA, all of these folks so that you are on solid grounds. That requires, and for this audience, having favorable regulatory environment, having strong policies that promotes this type of... This industry is hugely critical because the technology trend is unstoppable. It's going to happen. If you don't do it here, it's going to happen in China, it's going to happen in Taiwan, or it's going to happen in Europe.

But what is absolutely critical is knowing the building brand and the foundation of this business and how critical it is that if you take your eyes off the ball, and one of these for this audience is, you don't have good policies. You don't have favorable incentives. You don't promote the science and technology that feeds this industry, all bets are off, right? Because the technology is going to move forward. And we have seen this happening for the last three decades. And it's basically becoming, I would call it, endangered species in the United States. When you're down to below that 9, 8, 10%, you are going to become irrelevant. You're just going to become evaporating. It's gone. So, that's a problem for this industry. And we got to turn that around. We're extremely excited with the CHIPS Act and the elements that you mentioned that this is being realized and very, very exciting and this is absolutely critical time to really infuse that energy into this, unfortunately, downward trend that we got to turn it around.

Mira Ricardel:

So, that gets to the point of focus and implementation. Okay. So, the focus has to be on bolstering the U.S. semiconductor industry, not advancing technology globally. I mean, that will happen, but right now, the focus really has to be on prioritizing U.S. industry and making sure that the entire ecosystem and the entire journey from IP to production is supported in a U.S. government and industry partnership. And the regulatory policy is important as a former regulator. We have to understand what the impact of

regulations are on our businesses. At the same time, incentives are great, but if they're over-matched by corporate tax increases, that creates another problem. So, all of these legislative initiatives are exciting. I used to work on the Hill. It's always great to have these ideas come in, but on the execution side, we have to be very focused. Remember that the point of this is to maintain U.S. technology leadership, and to ensure that we have a robust and resilient supply chain anchored in U.S. protected and owned IP.

Jay Lewis:

And, Tom, maybe if I could add to that, you spoke about the Endless Frontiers Act, and we've talked a little bit about the CHIPS Act. And I wanted to address maybe what is in those particular piece of legislation, not to go through them in detail, but just really talk about the importance of the balance between them because I shared and Mukesh talked about his enthusiasm for the Endless Frontiers Act and the funding for its basic research. I completely agree. This is really focusing on the next generation of researchers that leadership technology leadership and things like photonics and some of the downstream technologies that will hopefully be emerging soon. It's incredibly important to invest there. I think that, historically, investing in research has been a little bit of an easy out for policy makers. We can all agree. It just sort of sounds nice and we don't really have to quantify it so much. It's going to pay off and we're just sure of it.

And so, we do that and we should. It's critical, but what I think is unique about the CHIPS Act and this sort of confluence of events today is actually connecting that to manufacturing. And that's a harder thing to do. The dollars that we're talking about are large. These are big investments that are required, and it's a hard thing to get sort of that policy and the political agreement on, but it is just as important. And if you are just doing the research and then things are made elsewhere, I think you're losing a lot of the advantage and the benefit of that research at the beginning. And I understand people are uncomfortable. Sometimes people are just uncomfortable with industrial policy or maybe they're uncomfortable with what seems like giveaways to these large corporations. It's important for people to understand that the manufacturing itself is... Today, there are barriers to doing that in U.S. We've sort of been playing an experiment for a couple of decades where other countries, other governments put their fingers on the scale and we see what happens. Keyvan talked about it. It's that trend of manufacturing going elsewhere.

And so, this investment is really needed just to have a level playing field and make sure that... I'm very enthusiastically supportive of all the research funding that's intended here, but I think we really need to take advantage of strategic opportunity to make sure that we continue to make the most advanced technologies in the U.S. as well. And to make that those are coupled together.

Tom Duesterberg:

An analogy with another current event, which is vaccine research and production, where we've come to learn that you can invent a technology, but putting it into place, actually manufacturing it, is very, very difficult, especially for things like biologics in the pharmaceutical industry. I used to run a trade association that did research on manufacturing in general, and some of the traditional industries, the heavy machinery guys, the aerospace guys, all said, "Unless you have research closely associated with geographically even with manufacturing, translating that fundamental research into actual products is more and more difficult." I mean, there's also the national security problem that we've seen more and more lately that if you're manufacturing abroad then the technology seems to leak or stolen. So, let me press Keyvan again. Have you seen that in terms of joining up research breakthroughs with actual manufacturing things yourself so that you would think it's doubly important to have manufacturing back on U.S. territory?

Keyvan Esfarjani:

Tom, what you're saying is actually the foundation of Intel's business model, which is, we do research and we transfer that research to high volume manufacturing, and it's like a tick-tock. You just keep repeating and rinse and repeat over and over and over again. That has been what one of our founders, and actually Mukesh referenced, it's called the Moore's law. Gordon Moore, one of the founders, basically said about 40 years ago that the number of transistors on a chip is going to double, and you can think that's on an algorithmic scale. And that has happened. There's not a formula, there's not a playbook behind. It's just a human drive that's enabling. And the way that works is you do research, you do the... It starts with really crazy ideas. Just all pie in the sky concepts, then you start implementing that into an R&D facility. So, you can actually see the chip, the circuit that actually works with the advanced materials like Mukesh was talking about. And then you say, "Okay. Now, there's some... This thing actually powers on. Okay. Now, let me take it to the next level and see, can I actually make it in mass production?"

Now, Intel has always kept the center of all of its research and development here in U.S.. By that, I mean, we have two big R&D operations that we invest billions every year. One is in Oregon, that does our Silicon process. And the other one, which is becoming more and more critically important, is the advanced packaging technologies. And we have that in Arizona. Those are sort of the two heart of the organs of how this company operates. And then from there, then you find out those technologies that are created into high volume manufacturing, which we have places in New Mexico, Arizona, and even other parts of the world. And then from that, we also have our packaging technologies. But I mentioned of photonics, right? Photonics was also created in the U.S.. We have it produced in New Mexico.

So, yes. Absolutely. The research and manufacturing have to go hand in hand. You cannot just do the research somewhere else and then say, "You know what? I'm just going to produce the factories in, say, United States and then just call it a day." That doesn't work. You really haven't solved the root cause of this, which is getting down to the foundational technologies. If you don't have that, the whole game is over. You have basically... The fundamental of what enables this industry and the manufacturing, the heart of that is research, and it goes hand in hand. You need both of them. You cannot just focus on one and forget about the other one.

Mukesh Khare:

Yep. I think this is... I would like to add a few more comments. It all makes sense. So, I will also say that as a part of semiconductor industry in the U.S., there is several component of this ecosystem. Of course, manufacturing fab, which is extremely critical as we talked about, but how about the equipment manufacturing? Equipment are also at the heart of how you build a fab. How are the design EDA, the software that is used to design chips? We need to also... As we are looking at it comprehensively, we need to look at this semiconductor ecosystem and manufacturing and enabling of all pieces of semiconductor, which enables at the end to manufacture the chip. We have to look at it in that environment so that we are doing the right thing, we are providing the right [inaudible 00:49:51] so that every component of chip manufacturing that is needed, is thriving and it's being successful. Otherwise, the competition is just fierce from outside, especially, from Asia.

Yeah. If I may, that's an excellent point where to run a semiconductor operation, which is what I do for a living across the globe, it's not just the company itself. It's not just the Intels of the world. It is the infrastructure that you need. This is an operation that you need a very, what I would call, reliable utilities. You need to have power. You need to have water. You need to have all the supply chain around equipment, around materials. That entire ecosystem has to go hand in hand. So, as we are, and as the audience here who's obviously a lot more expert than I am in the policies and regulation is the overall infrastructure has to be looked at. And if you do not have, if that element of it is shaky, the supply chain

infrastructure or the parts supply for supporting this massive ambitions that we have to really regain back the U.S. leadership, if that element of it is not being supported, then the whole plan is going to be struggling. So, something to think about as moving forward with this overall strategy.

Tom Duesterberg:

Okay.

Mira Ricardel:

[inaudible 00:51:39] just very quickly. I mean, this is a remarkably complex industry and you have to take a holistic view and a strategic view. And that's when I talked about focus. Really have to understand the connectivity between not just the process itself and the suppliers and the customer base, you also have to really understand how every one of the policies that comes out or the incentives or the regulations, how they affect every piece of this ecosystem. So, holistic approach is essential.

Tom Duesterberg:

Can I just raise one very current question, which is, we've seen these supply shortages in, say, the auto industry and maybe consumer electronics as well. As we think about larger government support for fabrication plants and for research, is there any element of the current shortage? And these are for products that are not necessarily at the leading edge, the seven nanometers, five nanometer they're two or maybe three, sometimes three generations ago. Do we need to support more manufacturing capacity domestically for legacy chips that are important to industries like auto or consumer electronics? Should some of that money go to just building new production capacity that's not necessarily at the leading age? But it's still hard to do, I know. Anybody want to...

Jay Lewis:

Maybe a comment on that, Tom. A couple of thoughts. One is, today's technology is very quickly going to be legacy technology. This is a very fast moving industry. Decisions that are made sort of at the policy and the government level today are going to take some time to be implemented. The industry will have changed by the time the first Silicon paid for by the government actually comes out. Personally, I think, it's very important to invest in the future. There are, again, very strategic opportunities and I do think it's very important for policy makers to understand that this is not sort of a one-time investment that's required. It's encouraging to see that the CHIPS Act has a 10 year time horizon. I think that's sort of the minimum you should be thinking about in terms of this area. If you carve it up too much and the money is gone in five years, you have a problem because... I mean, I think, Keyvan could tell you if you're not continually building capacity and upgrading old capacity and continuing to stay at the leading edge, you're out of the game. And so, I think... Personally, I think, investing in the future is kind of where policy makers should be.

Keyvan Esfarjani:

Yeah. I will agree with Jay. I would just add that the legacy capacity is something that... To your point earlier, places like China or some of the Asia countries have been having sort of thriving on. They buy all the equipment. And it's a very, very... I would say legacy technologies and they could get good margins out of it. But back to the question of the supply chain and balancing that supply chain, you hit on a very critical issue, which is that legacy also has to be looked upon. And that's something that needs to be invested and supported. And this is part of our... One of the recent announcement that Intel relayed to

the world was our IDM 2.0 strategy, and which was a recommitment to and doubling down on internal manufacturing. Utilizing external supplier wafers, where it makes sense, to deliver leadership products.

And, thirdly, is a new foundry business, which encompasses both the leading edge and legacy nodes where appropriate, where we can apply Intel's legacy technologies to deliver some of these shortages that you talked about. It requires commitment at the highest level of the company to make sure those areas are supported. And I know our CEO, Pat Gelsinger, has been quite vocal about... We need to be supporting all elements of the supply chain to regain back U.S. leadership in the semiconductors.

Tom Duesterberg:

Okay. We're nearly just end of our timeframe. Jay, one last comment.

Jay Lewis:

Oh, sorry. Just real quickly. By the way, congratulations to Intel on their IDM 2.0 announcement. I think that's very exciting. Yeah, I just want to add that-

Keyvan Esfarjani:

Hope you would like it.

Jay Lewis:

... there is a national security aspect of this. There are niche technologies, specialized technologies that don't really have the consumer demand, commercial demand that the government does need to pay attention to. And, historically, the DOD has done that and should continue to do that. So, sometimes those look like legacy technologies. Often, they're just very specialized things that are sort of off of the commercial path and that should be considered as well. It's very important to maintain.

Tom Duesterberg:

Okay.

Mira Ricardel:

I can only echo that as a former deputy national security advisor, we have to be purposeful, persistent, and remember at the end of the day that however we build our economy, it ends up being critical to our national security. And technology leadership is foundational to that as semiconductors are foundational to technology's leadership.

Tom Duesterberg:

Okay. Well, I think we've just about reached the end of the time that we had set for ourselves. And we try not to keep our audience much longer than an hour. So, I want to thank each and every one of you for a really interesting and insightful conversation. And this is a subject that we at Hudson are continuing to follow. And I hope that at some point in the future, we can get some of you back to comment on some of the things that are unfolding in real time here in Washington. So, thank you very much.

Keyvan Esfarjani:

Thank you.

Mukesh Khare:

Thank you.

Keyvan Esfarjani:

Pleasure to be with y'all. Thank you.

Mukesh Khare:

Thanks for a great-