【Samsung Electronics' 2018 Investors Forum】

Sang-Hyo Kim

Good morning. I'm Sang-Hyo Kim from Samsung Electronics IR. Thank you for attending Samsung Investor Forum in Singapore.

Usually, we have our -- the Investor Forum once a year. Last year, we had that in Hong Kong. But this year, we choose Singapore. After that, actually, Singapore is getting more popular place for very important meetings such as coming political big meeting.

So right. Anyway, yes, I'm very happy to be here in historical scene.

Today, we -- as usual, we prepared 3 topics. First, Vice President, Sang-Hyun Lee, Head of the Foundry Marketing team, will walk you through our Foundry business. With demand growing from areas such as AI, 5G, IoT and automotive technology, the importance of advanced process technology is rising.

Thus, this session, we are focused on Samsung Electronics differentiated capability in continuously developing and utilizing next-generation technology.

Next, Yong-Suk Choi of Samsung Display will talk about our automotive OLED business. OLED panels have become a mainstream feature in the small and midsize display market, especially for smartphone. We plan to expand the scope of our OLED business. And from among numerous new applications, we see strong potential in the automotive business. Accordingly, we will provide an overview of our automotive OLED business, which will drive long-term growth based on advanced technology and mass production capability.

Last but not least, the topic is about server memory. Explosive growth of data usage and processing has sent demand for high-capacity memory, especially from the data centers. At the same time, we also expect to see new demand from new areas, including AI. For this topic, Senior Vice President, Se-Won Chun, Head of the Memory Marketing team, will offer insight into opportunities in -- and our strategies for the upcoming data-centric era.

I believe today's event will give you the future technology road map and growth potential of Samsung. Once again, thank you for coming. And right -- I would like to invite Sang-Hyun Lee.

Please welcome him.

Sang-Hyun Lee

Thank you, Mr. Kim. Good morning, everybody. First of all, I really appreciate your attendance here and your interest in Samsung foundry technology and strategy.

Today, I'm going to talk about 3 key items. First of all, I will briefly talk about the business update, and then I will talk about our process technology road map. We upgraded our road map based on last year's road map, after talking with a lot of customer base. And then, I'm going to talk about our platform solution. Platform solution includes all the IPs, libraries, infrastructure package so that we can provide one-stop service to our customers.

So the 3 key items. And 2 weeks ago, actually, we had Samsung Foundry Forum in Santa Clara, U.S.A., to announce our first year anniversary. We became independent business unit in May 12 last year, and we built a lot of customer base interaction after that. So I will, during my discussion, I will show you how we upgraded our infrastructure, our strategy based on those learnings during the 1 year.

Our strength, as you might know well, by working with memory and R&D center, test package center, we built very good technology node. Our technology has become world first in most of the key FinFET node. And we have been building infrastructures on top of it so that we can provide best solution to our customers. So after my discussion today, I hope you can find out why Samsung Foundry can become the world #1 provider, the total solution provider to the fabless companies.

So previously, before independence of Foundry, we had Memory and System LSI as 2 independent business units. Foundry was part of the System LSI.

So we functioned as IDM company. From May 12 last year, Foundry has become independent business unit. And we are getting support from research and development center, test and package center together. So those 2 units are supporting Memory and Foundry altogether. They provide fundamental research and fundamental key solution for FinFET and EUV technology and further. So now we are pure-play foundry provider. So customers are building trust based on our pure-play Foundry business.

Since independence, our President, E. S. Chung, some people may know well about him. E.S. Chung made trust as our philosophy of business operation. So to get the trust from our customers, we provide technology, operation, service. For technology, we provide process technology, the best process technology to our customers and infrastructure, which is very customer-friendly. And we also provide one-stop shop from the design, the very design of the customers to the fabrication of the wafer and the test, everything.

For operation, we try to strive to provide flawless supply chain management, and we deliver execution based on our commitment. And in terms of service, we try to provide best service beyond customer's expectation based on our experience and knowledge.

This slide shows our history as foundry player. In 2005, we started Foundry business using the bulk CMOS. In 2011, we provided first, world first high-k metal gate at 32-nanometer, and we started mass production in S2 fab. 2015, we became the first FinFET provider in the whole world using the 14-nanometer. And our 14-nanometer, I will talk about 14-nanometer evolution later. We provided 14LPE for the biggest IT fabless companies, including System LSI, Qualcomm, Apple.

And then we also provided 10-nanometer in the industry first, and we made evolution to S3 line for 10-nanometer and 7-nanometer, and we are building EUV -- full EUV line in Hwaseong.

We have many manufacturing sites worldwide. First, our S1 line is in Giheung, and it makes 65-nanometer and the below. And we have 6-line, Line 6 actually, which provides 8-inch, 8-inch. I will talk about the details of the 8-inch later.

And our S3 line provides 10-nanometer and the 7-nanometer in Hwaseong. Actually Giheung, Hwaseong, they are very close. So you can just think they are very close altogether. S4 line provides CMOS image sensor using 45-nanometer and below process node, and we are building EUV line. We started constructing in February this year.

We have S2 line in Austin, Texas, which fabricates primarily 14-nanometer, and it expands to 65-nanometer to include all the legacy process nodes.

And we have 2 test and package centers: one in Suzhou, China, the other in Onyang, Korea. So by having these manufacturing sites, we strive to provide one-stop service to our customers so that customers can enjoy the fast time to market.

This year, we expect the Foundry business, the overall worldwide Foundry business to grow by about 5% or little bit more than that, and the total revenue should be around $63 billion. As you can see in the bar chart, most of the revenue increase will come from the advanced nodes, from 20-nanometer, 14-nanometer, 10-nanometer, including the competitors' 16-nanometer and the beyond as well.

When we had 130-nanometer foundry, there were 22 foundry service providers in the whole world. But now at 10-nanometer and 7-nanometer, there are only 3 foundry companies. So you can see that Samsung remains as one of the 3 foundry provider on the beyond node, and we will keep on striving to become the best technology solution provider here.

Last year, we reported $9.8 billion of revenue, including the System LSI as well. And we are expanding the system, not just System LSI, System LSI has become little bit less than half of our revenue, and we are actually expanding the customer base significantly. And compared to about 2 years ago, our customer base was doubled now. At the end of this year, we expect huge growth in terms of customer base.

So the reason why we could expand the customer base, you can see here. From the advanced technology node to latest technology node, we are providing evolutionary process node on each node.

We add RF technology for IoT companies, automotive, and we also add derivative process nodes for 10-, 8-, 7-nanometer. So the customers can choose the process node based on requirement. For performance, they will choose 7-nanometer and 8-nanometer. For cost base, they will choose legacy to 14-nanometer. That is our basic strategy.

Next, I'm going to talk about our process technology node readiness. This slide shows our basic strategy of process node migration. First, starting from 14LPE, here, the first FinFET in the whole world, we provided 10LPE by using pitch scaling and new process architecture. And then we are going to provide 7-nanometer LPP using another pitch scaling and also EUV line. From 7LPP to 3 GAA, GAA means Gate All Around. It is fundamental change of the MOSFET structure. And this will be another groundbreaking technology. We are going to provide this one as the sole provider, I believe. So from 14LPE to 10LPE, 7LPP, 3GAAE, there are always innovations of process technology, innovation of libraries.

On top of that, we are providing evolutionary process node migration. As you can see here, from 14LPE, we provided 14LPP. E means earlier version.

So E was used for most of the top tier companies, who doesn't need full set of libraries. 14LPP, P means performance. And we provide 14LPP for general customers. So we provide full libraries, full IPs and all solutions package as well. And then, for cost-sensitive customers, we provide 14LPC.

And another upgrade -- upgraded performance, another cost solution, 11LPP is up to now our best cost solution on 14-nanometer node. And I think this is very competitive. Even compared to other foundry service providers, I think our PP, performance power area is one of the best. So right now most of our customer base is 14LPC, and it is migrating to 11LPP now.

10LPE same likewise, we provide 10LPP, 8LPP, 8LPU. And the cadence on each node migration is 1 year. We provide derivative nodes every 1 year. Starting from 5LPP, there was some upgrade of our road map compared to last year's. We provide 5LPE, which is easy migration from 7LPP so that we can provide a very performance-enhanced version to top tier companies. And 4LPE, 4LPP will be mass production process node for global customers.

The reason why we numbered the 7, 5, 4, 4 was based on our EUV technology and our working with research and development center, we could provide very enhanced process technology where you can see that in a single box here, the design rule is very compatible from 7LPP to 4LPP, the basic design rule is very compatible. Or the 4LPP design rule is superset of 7LPP, meaning that even though you migrate to 4LPP, you can use the IPs built on 7LPP. So customers can enjoy easy migration using our technology node migration here.

This shows the road map on time line from 2018 to 2021. We already prepared 14LPE to 14LPU, 10LPE to 8LPP, and we are going to risk produce 11LPP and 8LPU now. And on the second half of this year, we are going to risk produce 7LPP, the first full EUV technology. And next year, we are going to risk produce using 5LPE and 4LPE, and then 4LPP and 3GAA will follow.

As for 7-nanometer readiness, the picture here shows that our fab using NXE:3400 equipment, EUV lithography tool. And on the right side, you can see our wafer per day capability. So right now, we are approaching to 1,000 wafers per day. And around 2020, we expect to provide 1,500 wafers per day. Most of the increase of the capability comes from source power. We already demonstrated 250-watt source power. And other 2 items are high-sensitivity resist -- photoresist and also the availability improvement, which means that for EUV, we can almost fully utilize the EUV equipment all day. Theoretically, there is some period EUV should shut down a little bit because of the -- sorry, I just forgot the terminology, but EUV equipment should have some break time. But based on our technology migration, technology innovation, we could increase the availability.

This picture shows the mask defect. And Samsung is the only company, who can use the mask defect inspection tool. Other foundry does not have this tool. It is because since working with the Memory, we developed the EUV defect inspection tool from the R&D center, and we can fully utilize this one to inspect the defect.

The layout on the bottom line shows our migration from 5-nanometer to 4-nanometer. As you can see, there are some technology like [MDB1 Fin] and others, which can help reducing the layout area. So those layout area reduction

come first of all from back end of line. So there are metal design rule changes and also some of the library innovations.

On 3-nanometer, first of all, let me introduce our 3-nanometer GAA technology here. This is the picture showing how our 3-nanometer is built on.

So we call it MBCFET, which means multibridge FET. You can see that 3-nanometer is built using 3 stacked gates together. We are stacking 3 altogether, and we also provide variety of width starting from the examples 15-nanometer, 30-nanometer, 45-nanometer. So 15-nanometer can be used for high-density design and the low-power design, while the 45-nanometer can be used for high-performance design, and you can see variety of layouts so that this is for high performance, this is for high density.

And the -- our research center developed the device so that it almost approaches the ideal limit, fundamental limit of the CMOS performance. This is kind of subthreshold characteristic. [Physicians] and engineers usually believe 65-nanometer is the ideal limit of FinFET, and we approached this one using our 3-nanometer Gate All Around technology.

So on top of the FinFET and EUV technology, we provide differentiated technology on the legacy nodes starting from 28LPP going to 18 FD-SOI.

So we have numerous volume productions using 28LPP plus eFlash, and we are adding RF on top of it. So they are used for IoTs, securities and MCUs. And there are many companies, who require much lower power than 28LPP. So we provided 28FDS -- FD-SOI. We worked with STMicro to develop this technology, and we are now mass producing using 28FDS. We provide RF capability. And by working with Tier-1 customers, we are mass -- we're going to mass produce EMM on top of 28FDS as well. They are utilized for automotive and MCU businesses.

Next year, we are going to provide 18 FD-SOI. And on top of FDS18, we will provide RF and EMM together. So basically, these differentiated technologies are very useful for consumer devices and automotive devices, which require very low power and high performance together.

This shows our 8-inch process. Primarily, until 2016, we worked with System LSI for those businesses, including eFlash, power, driver, CMOS image sensor. From the second half of 2016, we expanded customer base. We provided these technologies for global customers. And now we have customers using our fingerprint technology as well. And this fingerprint technology starting from 180-nanometer for LCD, now we (technical difficulty) for Fingerprint On Display, FOD, which is utilized for OLED.

eFlash is also advancing, starting from 65-nanometer now we provide RF capability and automotive Grade 1 capability. So they are used for many customers now. Likewise, power is very popular now. So we provide both mobile power and general-purpose power, which has 90-nanometer plus high voltage above 35 volt. And for general purpose, it goes above about 70 volt. So our customer base is expanded first in China, second in U.S.A. and third in Eastern Asia now, and we are also expanding customer base in Europe as well.

For the future business, we provide variety of advanced package solutions. First of all, we are very close to mass producing using this fan-out PLP.

This is an example of fan-out PLP technology: memory, logic stacked using the fan-out PLP, and this will be used for next year's mobile phone.

We also provide I-Cube technology, which is Samsung proprietary technology for 2.5D, and we have the capability for 4 HBM stacking right now.

And we are preparing 2.1D as well, which is based on RDL technology to provide 6 HBM and HBM together 8 HBM together.

We have some discussion with customers, who like to build 3D SiP. So on top of logic, it could be SRAM, it could be some kind of DRAM or logic-to-logic stacking. Since we have numerous experiences on HBM and CMOS image sensor to make the 3D stacking, we are going to provide this technology for AI, HPC and other areas as well.

Now let me move on to Samsung platform solution, especially I'm going to talk about our solution for AI, HPC and connectivity solutions. So AI is categorized in 3 areas. For cloud computing, people use this HBM 2.5D, 3D technology.

For edge computing like mobiles, automotive, people will like LPDDR and also GDDR as well. And IoT, simply IoT consumer devices like speakers, wearables, they will use LPDDR and low-cost solution.

So we are preparing for those 3 areas.

So how we prepare for those AI and HPC? Since we have experience working as IDM company, we know how to start from the very design wafer manufacturing, test and packaging and debugging, altogether. We have those things in Foundry business unit, and we are talking with customers.

We are providing our total solution to our customers. Examples are memory and SerDes interface IP, libraries, analog solution, security solution.

They are not just simple IPs, we provide total solution to our customers so that by using, for example, our analog IPs, they can optimize the top level architecture.

We also provide design methodology and power, signal, [Internet] solution altogether. And this is not all, we built SAFE. SAFE is Samsung Advanced Foundry Ecosystem. So Samsung's ecosystem. We have about 50 partners to participate in this SAFE ecosystem. The key members are shown here.

So we provide full lineup of design infra, and also we can provide total solution, including memory and package as well.

And on the package, we just not provided the hardware package. We provide design for testability and the power, signal, Internet as well. For 2.5D using HBM, the debugging is very serious issue now for many big customers. So we work together with our partners and also memory company to provide our proprietary solution for debugging. By using our debugging solution, they can easily debug the issues. So by having these solutions, we can provide short turnaround time for customers, and they will enjoy fast time to market.

This slide shows some examples of our SAFE ecosystem. So we are building IP and library very significantly. We have invested significant amount of money and resource, starting from late 2016, and we are building most of the key IPs

working with these companies. And we also have strong partnership for EDA design methodology, and we are expanding the design service partners as well.

This list shows the key examples of our design, infrastructure and the package infrastructure. For memory interface, HBM2, 3, GDDR6 are the key IPs, and we are not -- we have been not the #1 provider. But from now on, for HBM2 advanced version of 3.2 gigabit per second and GDDR6 of 16 gigabit per second and above, we will become the first provider. And that's what we try to be. We are investing significant resource for those IPs.

Likewise, for SerDes, we provide up to 112 gigabit per second SerDes and for a variety of die-to-die interface as well working with Synopsys, Cadence and Rambus. Okay?

Our security IPs are one of the key IPs for HPC and AI because the Big Data should be protected very carefully, and hardware security IP is very important because software security is always prone to hacking, right, but we have fundamental solution to provide those hacking using our hardware IPs. PUF, physically unclonable function, is one example. And on top of it, we provide 3 items: anti-hacking solution, chip-to-chip authentication and the secured DRAM protection. This shows our example of security platform solution. We provide all security IPs and software altogether to our customers so that they can just use as turnkey solution.

As for DRAM. Many security solutions should sacrifice the DRAM access bandwidth, but we have our proprietary technology so that the DRAM access bandwidth cannot be sacrificed. That is our solution we already provide to our customers.

And this is another key differentiating factor of Samsung Foundry, one-stop service. To provide true one-stop service, we should be able to provide from the very circuit design, wafer manufacturing, packaged turnkey solution, testing altogether. So especially for the fabless companies like AI, they do not have enough engineering resource. So they highly rely on this one-stop service. We already have those in our business, and they just provide the idea and top architecture, and we do everything for those customers.

So for circuit design, we use our internal ASIC team. We also use our design service providers here. Likewise, in packaged solution, we could provide packaged turnkey solution, meaning that we can provide HBM 2.5D package and ASIC service altogether so that customer can get seamless service from us. They don't have to worry about the HBM inventory. They don't have to worry about the debugging.

Let me move on to connected solution. We see that the trend is moving from PC era to mobile era, now IoT and automotive era. The number of connected devices will approach 125 billion in 2030. So we see a tremendous business chances in this area, and we are building a platform solution for mobile, IoT and automotive.

For mobile, especially for 5G, we already provide 14LPC RF for top tier mobile companies, fabless companies. And we are also going to add 8LPP RF and 7LPP RF. For lower-power solution and for lower-cost solution, we provide 28FDS RF and 18FDS RF. And you can see here that we are already the world first mass production company for FinFET RF, meaning the 14LPC RF is already used.

For automotive, we prepared to meet the AEC-Q100 Grade 1 qualification. And 28LPP to 10, 8LPP, we finished the qual of all the process nodes, also IPs. And at the fourth quarter of this year, we are going to provide the solution on 7LPP.

For IoT, low power and connectivity nonvolatile memory is the key for IoT. So our solution is 28LPP RF eFlash is one solution and 28FDS plus RF plus EMM is another solution. And we will provide 18FDS as well. And we are working with library companies and our IP partners to build IoT platform solution on top of these process nodes.

Okay. Let me summarize on our connectivity solution. For mobile and connectivity, we provide silicon-proven RF process technology. And we also provide RF millimeter wave support up to 110 gigahertz. And we provide special technology -- packaged technology, antenna [radio] technology so that customers can use the package as the antenna solution. For automotive, we already provide AEC-Q100 Grade 1 from 28- to 8-nanometer and we will provide 7-nanometer solution by fourth quarter of this year. And IPs are also

ready to meet the ISO 26262 certification. And we can provide automotive service package as well.

For IoT, we provide FD-SOI technology with RF and EMM capability, and our proprietary security IP and total solution on top of the IPs. Our IoT reference platform can be used for their easy design. And we have strong IP team, who can customize our IPs if they need different solution.

Okay. So I talked about 3 key items of Samsung Foundry. One thing is our business update and second thing is our technology road map update.

The key update on technology road map, just summarizing it again. Last year, we announced 4LPP as the Gate All Around. We changed the name to 3LPP, and we pulled in the schedule by 2 quarters because our R&D center found out the solution earlier than we originally planned. That is the key difference.

And 4-nanometer moved on to FinFET process family because we further found out process migration from the FinFET technology to 4-nanometer. I'm very proud that we can provide 7- to 4-nanometer as FinFET family. We can provide 3GAA, world first solution, Gate All Around solution. I'm very proud of it. And I just talked about the platform solution for AI, HPC and connectivity as an example. We can provide those kind of solutions for automotive, for mobile and for consumer as well.

So I think that one change of trend is from just a pure foundry provider, the foundry company should provide turnkey solution. The key is package solution, ASIC solution, IP solution. We are, I think, ready to provide on 14-nanometer and 10-nanometer. We are building those solutions on 7-nanometer. So I hope you found out Samsung Foundry could become a strongest foundry provider.

So thank you very much for your attention, and please have a good day. And my -- after my discussion, there will be LED and Memory discussion.

So please enjoy our discussion. Thank you very much.

Yes. So please give me any questions, but today, please confine our discussion on our process technology and platform solution, okay? Yes.

Q&A

<Q>: Yeah. Hi. Thanks for the presentation. First question is on Gate All Around. Could you elaborate a little bit on the key process challenges in bringing Gate All Around away from FinFET and the time line for risk production at this stage? Second solution just rebounding on what you just said, you alluded to packaging potentially being a key differentiating factor, effectively only over Foundry, which has this internally in terms of advanced technology apart from wafer-level packaging and 3D will be actually Intel. So how do we -- how do you look at packaging and packaging solutions as differentiating factor to win business, especially in AI vis-à-vis your foundry peers? Thank you.

<A>: Okay. Sorry -- can you repeat your very first question?

<Q>: Very first question is regarding Gate All Around, GAA, what are the key process challenges in forming the Gate All Around versus normal FinFET structure? And with that in mind, when are you targeting risk production?

<A>: Okay. The reason why we developed Gate All Around, first of all, the purpose is that from 14-nanometer, 10-nanometer, 7-nanometer, even though we could get performance enhancement, size reduction, the fundamental limit was we could not scale supply voltage. Supply voltage, it was always 0.75 volt. That was physical limit, fundamental limit; not just for Samsung, it is the fundamental limit of FinFET technology itself. So we pursued a very different solution. Gate All Around, the difference of Gate All Around is FinFET, the channel is surrounded by gate in 2 dimensions, right, left side and right side. Gate All Around is very different. Gate All Around surrounds the channel in 4 dimension. So that could enhance the channel mobility, I think, the current capability. And as we just saw in the picture, we built MBCFET using 3 stacked Gate All Around devices. We could enhance the current capability of those devices. I'm not a guy on process node, but I think the Gate All Around is not easy to develop. There will be a lot of defect issue using Gate All Around, reliability issue as well, but we already demonstrated some silicon performance on papers, and we also demonstrated on our [process] press release as well. So I'm very comfortable that Samsung Foundry will be the only provider of Gate All Around technology. In terms of mass production, it -- we -- it highly depends

on customers' adoption of Gate All Around, and we started -- just started talking with Tier 1 customers. So the time line of mass production is not decided yet. For the package, your question was our packaged solution for AI, HPC, those areas, right? Okay. Our package solution for AI, HPC, as I mentioned in previous slides, our key differentiating factor on 2.5D is we can provide turnkey solution because we could control the memories. We could control the ASIC. We could control 2.5D package altogether.

This is not just within the Foundry business unit, we will work with our OSAT companies. We already have collaboration with OSAT companies to provide this turnkey solution. The key is our customers will not see the barrier between OSAT companies, us, ASIC service providers. We will be in charge of everything. And to build those solutions, we built our own proprietary debugging solution because the debugging solution – without debugging solution, we cannot say we are the turnkey solution provider, right? So we will let customers free from the debugging issue. We will work on it. And we already have some experience. The reason why we could provide this experience was, we worked as IDM company. And for mobiles, for example, when we provided memory and IP together, we worked together, and we have good design methodology team, who can find out the debugging solution. It can be used for 2.5D package as well. Okay. Thank you. Okay. Yeah.

<Q>: One question on the slide, the IoT and FD-SOI. And what is the benefit of fully depleting silicon on insulator? And why did that technology – why was the technology applied from the IoT first? And as far as I know generally, the benefit is high performance and low power, right? So are there at least the special benefits of those technologies?

<A>: Actually, you are right. High performance and low power. The advantage of FD-SOI is, when you use FD-SOI, the difference from bulk MOS is, you can control the body bias. By controlling the body bias, you can change the leakage current significantly. By changing the body bias by, for example, 1 volt, the leakage power can be reduced by 1/10 of the original leakage. And also dynamic power is also controlled. Dynamically, you can control the dynamic power by adjusting the adaptive body bias. So I think that is the key technology difference. Another thing is FD-SOI has better quality control compared to bulk

CMOS. So quality control is better if you use FD-SOI. And that's why our some Tier 1 customers early adopted FD-SOI technology. NXP was one example. NXP already announced press released a lot of times. So they were, I think, the first mass producer of using FD-SOI, and they are really enjoying the benefit of this one. And they like [to stuck] to 28 FD-SOI and move to 18 FD-SOI. We also have multiple Japanese customers, who like to use our FD-SOI technology -- 28 FD-SOI. They already started designing. They are close to mass producing. And I believe this technology can be expanded to Tier 2, Tier 3 customer -- consumers as well. We have multiple, for example, printer companies, who use 28 FD-SOI. So on consumer side, 28 FD-SOI will be cheaper version, low-power version. So it will be very popular.

<Q>: You mentioned earlier about doubling your customer base and having that increase -- you saw increase from China in a significant portion. Could you elaborate on what kind of applications are this for? And then my second question is also on cryptocurrency. What is your exposure to cryptocurrency? And on the third question, it's on 3GAA. Could you elaborate on why is this a breakthrough technology? And what kind of applications you see this for?

<A>: Third question was?

<Q>: 3GAA.

<A>: 3GAA, you meant Gate All Around?

<Q>: Yes. That's right. Yeah.

<A>: Okay, okay. First question was what kind of area we expand the customer base in China. Our key area is mobile, consumer, automotive, HPC and network.

And I think we expand in all those areas in Chinese market. I think the key difference -- one of the key differences in Chinese market is if they feel our process technology is attractive, they take it very quickly. Chinese customers move very quickly, and that's why we could expand in China in a very fast way. I could not show the detail of the companies, but we are really expanding in Chinese market. And second thing is cryptocurrency. We work with new numerous cryptocurrency, especially Bitcoin, Ethereum and the Litecoin companies. And I think the demand is still quite strong. Demand is quite strong.

But in the long term, we are carefully investigating how long it will go and how significantly the business will change from our customers and the said companies, mining companies as well. So we are still starting on it, but this year, we have pretty good business on cryptocurrency area.

<Q>: I have a follow-up question on the -- on China, right. So can you help me understand what has changed such that in this year you are seeing an increase in terms of the customers from China?

<A>: Sorry, I didn't get.

<Q>: What has changed in terms of seeing that increase in terms of orders in customers from China?

<A>: Increase of -- sorry, I didn't?

<Q>: Increase in the orders from China. What has changed? Because previously, the orders from China was relatively muted, if I understand correctly, but now that has changed and you are seeing a substantial increase and you've doubled your customer base. What has really changed in this year?

<A>: I think one of the reason is since we prepared for the turnkey solution, total solution. Originally, we had some limited capability in terms of the IP, in terms of the design solution. But now we strengthened significantly. I think that's one reason. Second reason is, I think the -- since Chinese Semiconductor business is very good that is another reason I think.

<Q>: Just a question on returns. So it seems as if since 2005, you did spend quite a bit of capital deploying to the mobile Internet era. But looking at the returns on the investments, were okay, weren't great. And as we move into this IoT, AI and autonomous, it's a step change. Maybe the -- it's more level-playing field against the #1 player. So do you feel that returns on those investments are different this time around as we move into this data era?

<A>: Yes. We are enhancing the return on our investment, and it depends on the business volume. So first of all, we try to increase our business volume.

And I think the return on investment will follow. And for more details, since we are going to have IR in a month later, I appreciate you to join our IR. We are going to talk about the financial status.

<Q>: Simon Woo from Bank of America Merrill Lynch. Just a quick question on the EUV area. So do you really believe the EUV needed for the application process that [shift] maybe from 2020 or read out EUV. Just multi-patterning is not enough for 2020. And then the EUV fab for 2020 we guess, exclusively EUV fab. That fab will be only for EUV process or for other lithography process as well?

<A>: Our S3 fab -- first, let me answer to your last question. Our S3 fab was the first fab to provide EUV, but S3 fab has mixture of full EUV and the non-EUV, like 10 nanometers and the others. And I mentioned about pure EUV fab. It will provide the EUVs or EUV process, 7 nanometer and beyond as well.

That is my answer to you. And my -- your first question is very hard to answer whether you really need EUV only? I believe so. Because EUV only can provide much less cost because if you go with EUV only, you can reduce the number of masks significantly. It is more than just simply 2 digit compared to non-EUV version. So eventually, for top tier and advanced node, I believe that you should move on to full EUV like Samsung provides.

Okay, I think the time already passed. So thank you very much for your interest. Okay. Thanks very much.

Sang-Hyo Kim

Thank you, Mr. Lee.

Yong-Suk Choi

Okay. Good morning, ladies and gentlemen. This is Y.S. Choi working for Samsung OLED division and then this is my great honor to present Samsung OLED display for the automotive market.

Okay. Today's -- my presentation consist of 3 parts. Basically I'll briefly touch about the market dynamics of the small and medium display market; and secondly, why Samsung OLED could be the solution for the automotive display market; and then, finally, I will talk about our Samsung Display's strategy for the automotive display market.

Okay. This is the snapshot of the small and medium -- small and medium display market. Basically still mobile phone. This is talking about just production area size, in terms of production area. Below 13 inches. Still, the smartphone and the mobile phone market consist of more than 60% of the total production. And secondly, the tablet 8-, 9-, 10-, 12-inches tablet, consist of the second biggest market. But definitely, this market is not growing. It's decreasing actually. And then interestingly, automotive market, overall, this one is the third biggest market in terms of the small and medium display. But CAGR, annual growth rate, is almost 2 digit, grow very close to the 2 digit. So basically automotive display market has 3 or 4 different applications, basically CID, center information display and then display for the instrument clusters and rear-seat entertainment, and interestingly, head-up display and then (E-Mirror) display, it is kind of new applications coming into the display market. Okay. This one is showing about the automotive display market with applications as we -- as I introduced earlier. So still more than 90% of the display market dedicated for the CID and then cluster market. But as I said that interestingly new kind of applications, head-up display, rear-seat entertainment, and then [seamless music coming on] monitoring system for the display is booming up now.

But if we talk about the display technology, so as everybody knows that this TFT display, LCD has theoretically almost 100% of the market. But according to the IHS, they say 2 years later, maybe 1 million; another 4 years later, maybe 3 million OLED display will be in the market. So this is the current market forecast and expectation for the automotive display market.

So I just want -- as a OLED display maker, I want to more talk about why future automotive display market need more OLED displays in the market.

First, as everybody knows that the OLED display is much better optical performance than LCD displays. So people, the normal consumers already experience the very, very good display quality through their smartphone displays. Previously, when we talk about just the display and then in the car, just simply we are talking about the size. "Okay, you have a 5-inch display and 7-inch display. Oh, you guys have a very good displays, 10 inches or something." But now people are talking about their quality. Every 6 months and 1 year, normal consumers see the very cutting-edge smartphones with very beautiful displays. But they are frustrated when they go into the car buying shops and the display is just outdated. That is the biggest challenge for our customers, OEM customers and the Tier 1 customers. That's why they have very aggressive discussions with us, how they can close the gap between the consumer experience versus their kind of the -- their consumers already experienced the kind of the experience to their car experience. Yes.

Second movement that we can address is that the evolution of the EV cars. So especially, after the dieselgate all of the OEM customers are very aggressively trying to introduce the EV cars in the market and then if we just talk about the just one display and 2 display in the car with a combustion engine, the advantage of the power savings of the OLED display, yes, that's nothing. But when we talk about the EV cars with many displays in -- under autonomous driving environment, this could be a very good differentiating factor going forward.

And the other point that we want to discuss is that OLEDs has a very thin and light form factor basically. And then so the car OEM designers kind of the -- always they have some kind of difficulties to just typically behind this display systems many cables and air-conditioning systems and they have a very limited space. But by adopting OLED displays, they can have more design flexibility. So these new factors having together, we may believe that the new kind of -- this kind of market expectation forecast will be changed if we think about this kind of new factor together.

Okay. For those of you who are not that familiar with the difference between OLED display and LCD display, I'm going to give you a brief introduction about the basic differences. So looks similar. This smartphone with OLED displays, smartphone with LCD displays looks very similar, but actual structure and then wiring method is totally totally different displays. So as you can see, OLED display has very simple structure. Just 2 bottom glass and top glass and then that's it. And they're no liquid crystal in between and they're no backlighting in it. So there is mechanically very thin form factor. And another interesting point is that OLED display is driven by the organic materials, which is self-emitting the lights. But LCD display case always there is some additional help from the backlight unit. And then in order to express the color, they also need this kind of color filter on top of that. So very, very complex structure. And another interesting point of the power efficiency. So regardless of the contents, LCD has to turn on 100% of their backlight unit. But if we just showed a 50% of the display images, OLED case, we just turn on just 50%. If we need just 5% of the content, we just need to turn on 5% of the power. That's why we can significantly save overall powers of the OLED display versus LCD.

And as I said that very thin and light form factor. So this is this kind of simulation of the display module. So 12 inch -- the 12.3 inch is very, very popular size for the cluster display. And then if you compare the overall size and weight, just -- OLED case has just over 100 grams versus LCD case is almost 400 grams. If you think about just the difference, it's okay, 300 grams. That's nothing, for the cars are almost 1,500 kilograms and then something. But if we think about EV cars and then times of 6 or 7 displays that could be a matter going forward.

Okay. Let's go to why we think that we can address why OLED display [to ascertain the] automotive market. So before we set up our strategy, we just sat back and then thought about our future plans, how we can address customers and consumers point with our OLED displays. And then from consumers point of view, we thought about our kind of the -- what's the difference of our displays. First of all, so as I said that consumers already experienced very nice displays with more than 10 -- almost 10 years with their smartphone displays. We believe that they want to have a seamless experience between mobile and

automotive. So like mirroring. So we can enjoy the mirrorings with our TVs and the mobile phones, why not in the 5G era, why not in the autonomous connected car environment? And then haptic and fingerprint on display, those kind of -- new kind of functions they also want to enjoy. And then definitely, they want to have a beautiful and then elegant interior design with the new displays. But at the same time, the car should be very -- we always thought about the concern about fuel efficiency. And then also concern about the safety because that the car is always moving.

So this is the summary of how and why and how we can address this kind of consumers new wants and needs. So basically, as I said that OLED display can give the very high optical performance with a wider color gamut and a higher contrast ratio. And then OLED can give them a very totally different form factor and then design possibility for the car design. At the same time, as I said that OLED can give a very benefit of the power efficiency. And then also OLED display can give them safety, enhance the overall safety. And finally, we can provide more values, additional values with -- from the smartphone and the mobile experience to the automotive.

So basically high picture quality. So OLED can -- because of the OLED has high -- very high contrast ratio, we can give them a very true bright experience versus LCD cases, there's some kind of the [liquidities] inevitable because of the technology itself. And then when you think about there's some kind of a dark environment and their dark and rainy-driving environment because of the higher contrast ratio, we can easily recognize the object with the dark environment versus sometimes it is not easy that kind of the environment with OLED -- LCD displays.

Additional point of the OLED display. Beauty of the OLED display has very wider color gamut, coupled with high contrast ratio. OLED can give -- very easily recognize the object in the display, with the same brightness level or much better recognition with OLED versus over LCD displays.

And interestingly, there is another -- we can give another additional optical values. So they have some kind of experiment. It is known to be had blue light. Hazardous blue light is very, very harmful for the human eyes. And that's the

experiment of the mouse. And after 24 hours of exposing the RGB light, and then 20% of the retinal cells survived. So that basically, hazardous blue light is very, very harmful for the human eyes and then the animals. And then when we compare with LCD display and the OLED display, thankfully OLED has a very limited, very much less harmful blue light versus OLED (sic) [LCD]. That means -- which means if you think about the autonomous car interior design environment when we have a very long drive within a dark environment, and we can easily feel some kind of eye fatigue. But OLED case, we can significantly reduce that kind of the issues.

And another interesting point is that this one. So it is known to be that 6% of the human capital of the men, not the women. 6% of the mens are color weakness people. So they have difficulties to recognize between the colors red and green. But OLED case, we can control each pixel by pixel.

That means we can intentionally increase the red pixel performance in the case color weakness people -- even color weakness people can easily recognize this kind of signals through the OLED displays. That's another interesting values that we can -- optical values can give consumers and then customers.

Next one is talking about the mechanical difference basically. So yes, this one is fundamental difference between LCD and OLED. Because OLED has very thin simple form factor and an even flexible substrate -- flexible display is possible. We can give -- not easily recognizable. This one is actually flexible display in the S curve, we call it S curve, double-curved display. And then we can implement this kind of -- this curvy designs with the flexible display easily. So this could be a very, very wow effect for the consumers and then OEM customers. So OLED case, no liquid crystal as I said that. No backlight unit, and then no color filter and easily bent, easily make some curvy designs possible. And then this is only -- it's another kind of the example of the -- so for rear-seat entertainment case, we can give them a -- because of their thinner light form factor, so we can give them a different kind of the design ideas. Right inside, this one is the -- the demo was introduced last week in the SID show in the Los Angeles. And then this one is basically low-level displays based on our flexible display. And then this one can be rolled up and rolled down. And then basically this one is 14-inch display. But if we use the 2/3 of the display, it can be 11 inches, 10 inches,

11 inches of display. And then if we rolled up a little bit more, we can use this one as a 9 inches -- 8 or 9 inches of display. And then at the same time, we can use this kind of additional space behind the display. So let me show you some video -- actual videos of this displays.

So 1/3 -- a 2/3 and a full displays and this kind of -- because of the flexible substrate, we can roll up and roll down. And then we believe that this kind of new form factor can give a lot of new designs ideas for the OEMs. This one -- we can show you that how this displays can be rolled up and rolled down.

Okay. Finally, I'm talking about -- [we'll actually call] difference. As I said that OLED is the content-based driving. That means we call it on-pixel ratio.

So when we need just kind of like dark cluster menus, we just need 7% of the -- we need just 7% of the power. Regardless of the contents, LCD has always 100% power should be turned on. So just -- the OLED case, we need 11% of the power need to turn on. And the video just kind of pictures the 17%, and then camera monitoring system just around is 30% of the power. And that twice the power needed content is about the navigation map and that's only just more than 50% of the power. So all things together, we can simulate a user profile. Usually, it has a 30% of -- we need the 30% of the OPR, on-pixel ratio. And then if we compare the overall power consumption versus 12-inch simulated at 600 [DPI] and then OLED case has just less than 50% of the LCD power.

If we think about just one display in the combustion engine that kind of the power saving is [minimis]. But if we think about the EV cars with the connected environment, with the more autonomous driving environment, which requires 6 displays and 8 displays and 10 displays in the car, this could be a matter. So this one is a simulation of the 6 displays with yes, 8-inch, 10-inch, 12-inch and their power -- displays itself power consumption is 26 watt versus LCD is just 46 watt. But the difference -- the [model] difference is just 1 kilogram versus 2.5 kilograms. This one is only just 1.5 kilograms difference. But with this kind of the flexibility, we can give power -- the OEM car designers, power management system, we can give them more flexibility and more rooms to install more kind of electronic devices. When we think about the connected cars and autonomous driving, many, many sensors around the cars and then, in that

case, the power consumption -- overall power consumption should be multipled going forward. In that case, OLED, if they -- if our customers used OLED displays, we can give -- we can save additional kind of the acid -- lead-acid battery.

So all things together, we can give them for example, 20 kilograms and 30 kilograms more kind of savings for the car designs. So that's the – those kind of benefit can combine and then if we combine those kind of benefits and that overall benefit will be much better, much bigger than typical 1 or 2 display comparisons.

Okay. This one is another kind of a new category and new applications. So now some customers, we are thinking about, talking about the eliminating physical side mirror. And then if we eliminate physical side mirror, we can have a very, very simple kind of very small kind of the form factor with camera models. In that case, they say sometimes 3% or 5% of more fuel efficiency with this kind of new designs. And by eliminating the physical mirror, they have to install the displays inside the cars. But the A pillar -- just below the A pillar, there is very limited space. And then -- so if we -- the OLED is very, very thin form factor, that's why they can easily implement, install OLED display in the car versus as is the case as basically much thicker form factor. And then more -- a lot of the heat is coming from the backlight unit. They also need a heat management, heat sink, heat management system with OLED -- LCD cases. In that case, it's not easy to install those kind of the camera monitoring system with the [e-meter] in the car. And another kind of basic differences is that, this one. We took the same video -- we took the video same-dated, played on the one with the LCD display and the one with OLED display at minus 20 degrees. In Singapore and a very hot humid area, we don't need to worry about 20 -- minus 20, minus 30 degrees, but this one is critical in the Norway, Finland and North Canada and the Michigan area, minus 20 and minus 30 degrees in the -- their winter times. And then because LCD case, liquid crystal doesn't move fast at very low temperature. And then this one is very, very critical moment. So 1.1 second that there could be almost 3 meters of difference of the recognizing the object in this passing by me. So OLED case is the no response time issue, so -- also we can increase our safety with OLED displays in the car.

Next one is another interesting new concept with -- by utilizing OLED display. So as I said that some car accidents happen when drivers try to change their settings in the audios and videos and they're some CID controls and they -- when they lose their eyesight. That happens. So that's why some kind of customers -- I mean, we have very -- or concept stage to what about installing the display on top of the steering wheel. And typically, display -- the steering wheel -- just below the steering wheel there should be, I mean, airbag should coming out. Because of that, some size -- the weight limit is. That's why LCD cannot make even happen and then even our rigid glass-based OLED cannot meet their requirement.

Usually about 40 grams and 50 grams. Only the flexible display can meet their requirement. And then when -- if we think about that what actually some display on top of the steering wheel, head impact happens. It shouldn't be breakable because some kind of glass breakage and that can damage the human body. This is why we thought about the -- what about the plastic. Plastic cover window on top of the display. And then we

make some kind of the demonstration and let me show you the demonstration.

So interesting concept, and the -- so basically, display is plastic and the cover -- cover window is plastic. So basically not breakable. And then very light form factor, so that's why we can provide additional innovative display concept for the automotive display. And then additional values. So Mr. Lee also talked about there's some kind of haptic feedback with our OLED display. The reason why OLED display can easily improvement is that -- this one is the mechanical form factor. So as I said that LCD has a liquid crystal in between, in the backlight unit and then very thick form factor versus our rigid display and then flexible display is very thin and light form factor. That means if we apply the haptic and fingerprint sensors behind the display, it can easily, easily transfer that kind of signals to the sensors. So that's why we basically -- haptic feedback and fingerprint on display, we can easily implement with the OLED displays.

Okay. Until now I have presented why OLED display can address new demand and innovative concept to the automotive market. But still, OLED display has some kind of the intrinsic challenges. This one basically, OLED display is driven

by the organic material, which means over the time with higher brightness, organic material can be degraded over time. And then, until now -- until recently, we had some kind of brightness versus lifetime issue, for the -- especially for the automotive requirement.

So we recently overcame that kind of basic automotive reliability requirement with the acceptable brightness and then acceptable reliability. But still some customers and then for the certain usage of their cases, especially, for the bright sunlight, direct exposure to the bright sunlight that they want to have higher brightness. So we are working on it. For the most cases, we overcame the kind of basic requirement, but some certain use cases, they pushed us to increase the more brightness. And then if we just simply increase the brightness, overall lifetime can be degraded. So we are working on it to achieve the higher to meet all those kind of requirements now. And then another -- the point is that image burning, so as I said that organic material is organic. If we turned on the simple, certain images for a long time, it can be degraded and then it can be less -- it can show the less brightness. This -- in automotive cases, we tested this one over thousands of thousands of hours, if we turn on the same images without changing the fixed images, then this area become -- looks like this kind of very little bit less brightness -- bright area that means image burning issue. But this one is actually happening for the -- so think about that so 3,000 hours, 5,000 hours without changing the image.

See OLED, in reality, that's not possible. But automotive customers always ask us to be perfect. That's why anyway we are working on to minimize.

We already developed that kind of minimizing algorithm -- our technology to be shown like this. So in real cases, we don't have any concerns and the OEM customers already okay, but they are still pushing us to upgrade more and more to avoid that kind of the potential issues.

So these are the kind of our technical challenges. Still, we are working on it. And then another point is that -- this one shows what mobile phone -- mobile phone display market. Sales revenue market share. This year, we expect to have more than 50% of the market share in terms of the dollar value. And then it took us more than 10 years in the smartphone and the mobile phone market.

And then -- so this one is challenging in terms of the commercialization of our OLED display into the automotive market. So we -- last year, we introduced some kind -- our OLED display in the newer car and then, according to the technology adoption life cycle, it is very, very early stage and then we need to closely work with our customers.

And then we know that, that's the long way to go especially in the automotive market, but we're going to entertain -- we're going to support with a very innovative OLED display going forward with the -- in the automotive market. So there's still long way to go, but we will go there.

Okay. This is the summary of our kind of double strategy for the automotive display market. Basically, we think that we have created OLED display market in the smartphone. So we first -- our mass production of the OLED display in the actual usage happens 11 years ago. And then cumulative, we have expected to ship 1.8 billion pieces of the -- this OLED displays in the market. And then this one is actual product we have worked with our customers. And then we introduced a very innovative technology with the OLED display for the mobile market for the past 10 years. And then we have a proven track record, why Samsung OLED in the market. So we have proven in the market more than 10 years with -- and also believe that we have created the OLED display market with the smartphone and small size display market.

And then, basically, we want to continue this kind of the proven track record and then our kind of the history in the mobile -- no, no. I'm sorry, in the automotive display market. So this year -- later this year, we think that there is another kind of introduction of the -- our OLED display in the market. And then later, as I said they're unbreakable and rollable and they're transparent and the new additional values on the OLED display. We will differentiate this with this kind of innovations into the automotive display market. That's our strategy again going forward.

Thank you for your attention. And then this is end of my presentation. If there's any questions?

Q&A

<Q>: Thank you very much for the presentation. You talked a little -- a lot about technological advantages. Can you talk a little about that cost advantage? Where is the current situation right now in the cost between the OLED and the LCD from the OEM perspective?

<A>: Yes. It is not easy to talk about just simply cost, full cost. And that cost always involved with volumes and overall project volume and blah blah.

And then I think that you are talking about when OLED pricing can be matched with LCD displays. That's the basic question. But we think that we -- if we deliver the very acceptable and the meaningful values to the customers, the price will be decided by market, not by us. So I think that we are closely working with our customers to have a right value point with the right pricing. So that's our kind of strategy to work with our customers.

<Q>: Thank you. Just to continue little bit on the cost side. From a manufacturing perspective, is it more efficient to dedicate lines potentially to automotive OLED within your Gen 6 capacity, or is mix and match actually absolutely fine vis-à-vis mobile, in particular? And secondly, could you elaborate a little bit on OLED versus micro LED especially for applications like HUD displays? Thank you.

<A>: Yes. So the market and the commercial dynamics is totally different from the mobile phones, which has big volumes and in OLED case, there is very kind of design-oriented custom -- maybe you need more custom displays in the smaller fabs. And then basically, yes, you already answered the questions. We have basically -- right manufacturing fab with the right kind of applications. So mix and match is basically our strategy for the manufacturing. And then for the micro OLED, micro-LED displays. And then we also saw some kind of the very nice demos and prototypes from our competition. So my personal opinion is that it takes time to be used in the automotive market. But we will see how they perform in the market.

And then -- so basically, now we are just focusing on the OLED display for the automotive. Okay?

Sang-Hyo Kim

Any other questions? Okay. Then we'll end up the second session here. Thank you, Mr. Choi. We will have about 15-minutes break.

[Break]

Okay. We're about to start the last presentation for today. But please no photos during the speech and only the questions related to topics made.

Okay. Please join me in welcoming Mr. Chun to stage.

Se-Won Chun

Can you hear me? Good morning in Singapore time. Good afternoon in Korean time. Very nice to meet you. My name is Se-Won Chun.

I'm very happy to be here today to make the presentation about data center era. Okay. My name is Sewon Chun, but my initial, S.W. Chun. When I dispatched to the United States, my colleague named me your S, Sean is better and Steve -- otherwise, named me Steve. No. And they are saying one day, suddenly [San Chun] is right nickname to S. So before I joined Samsung, S.W. stands for stupid and white. After joining Samsung, I tried to Smarter and Wiser. Today I have studied about the data center and this may help you to understand the data center market and how much impact this data center to Memory business and IT industry. So I will start with this.

Do you know who is this guy, this gentleman? You don't know this gentleman? This gentleman, Victor Hugo. What he said, "The cloud, the only bird that never sleep." So my topic today is the cloud. In the modern age, cloud are where data never sleep, continuously fueled by more and more memory. So this cloud is very, very important in our Memory business. So let me start here of this Victor Hugo's one quote, "The cloud, the only bird that never sleep."

Okay. Let me start with this slide. So this slide shows the memory revenue trend among all semiconductor industry. So when you look at this PC era, and there is a lot of up and down, up and down, but still keep growing. And only -- in that time frame, only memory revenue portion is only 15%, 15% only. But you can see here, after launching smartphone and then mobile portion is getting important for Memory business among all IT, semiconductor industry. And one smartphone launched to the market after that Android OS tried to catch up for this leading company for the smartphone and then smartphone business has been booming. That impact to mobile total Memory business, we call it mobile era. So mobile phone market right now, long time before in this time frame is skyrocketing. Penetration rate and the growth of smartphone shipment number has been skyrocketing in that time frame. However, smartphone shipment number is mitigated nowadays.

And fortunately, since 2016, data center market is booming. And means that, in other words, data center market booming, is the server market is booming. Server market impact to Memory business a lot in total semiconductor industry. But in the process, the memory, the role has been changed from just a passive component to being at the core of the IT revolution. So memory is going to be the very important role from now on for data center era. That's why I define from now on the data center era is just started.

And as you can see this chart, the cloud industry as you can see right now, we are here. Rapidly growing since year 2017, and 2025 $400 billion.

The main role of this data center revenue growth is data center cloud. Cloud is going to be a main role of this public and hybrid cloud revenue impact.

Okay. Let me switch the topic. Data center is the core of IT industry, as you can see here. Processing, storing, seamlessly connected for multiple application. As you can see, when the connected auto, connected car started and the data generated by huge amount of data by this application. And IoT, Industry 4.1, gaming, mobile, PC, to have this multiple connection, 5G infrastructure is required. You know why the 5G is very important for this data center and this semiconductor industry? 5G provide hyper-connectivity. When you look back at the 4G era, when the 4G launched to the market, that time frame, nobody

knows 4G how much impact to this semiconductor industry? In the end, we knew how much impact the 4G is going to impact, we already have seen the impact.

And 5G, the one very important message is hyper-connectivity. Right now, 4G infrastructure only connected PC, tablet, smartphone, very limited application is connected. But once 5G infrastructure deployed to the market, after that, many, many IT gadget connected. You call it IoT, Internet of Things -- many, many IT gadget connected through 5G. 5G is going to be big impact for this semiconductor industry.

Okay, nowadays data center business is booming, as you remember. Amazon, AWS, is leading this momentum. Why on-premise to public cloud. Why the company is trying to move their data, what their infrastructure to public cloud? There is 2 reason: customer point of view; and data center competition dynamics.

First of all, I would like to emphasize customer side. Why the dot-com company or Fortune 100 company, tried to have [inaudible] services from data center guy. Definitely, they have some benefit. First one is TCO benefit. As you can see, all the companies, big company and small company, they try to have their own data center, but cost-wise, it's too, too much big money to maintain, to sustain the service they want is very, very difficult.

They realized that, and also even small company, recorded SMB company, they are saying to build my own data center, it costs a lot. So that's why they're looking for some efficient way to have data center by their own, but they found out that TCO benefit a lot. And data center provides that company's economy scale they provide. Hyper-scale side, optimize and infrastructure standardization allow lower cost, that is the first priority why on-premise guy is moving to public cloud. And also, the other benefit is that though guy could try to build their own data center, but is they cannot have the most advanced technology or the most advanced computing architecture. But data center has a lot of capability to deploy their new technology, their new services, their new infrastructure, their new platforms immediately companies can adapt. That is the reason nowadays why.

[inaudible] that competition dynamics for the data center guys. Amazon is leading this industry at the moment, and as you can see of this slide, number of services is kind of skyrocketing. CAGR 45% here. Amazon leading this industry a lot because they have a lot of capability, they have a lot of resources and how about the other guys, Microsoft and Google. And now, there is China data center like, we call it BAT. Baidu, Alibaba, Tencent. That is the reason why on-prem guys do public cloud.

But based on my understanding, data center is just started. It's just started. When I look back 2016, and 1 year before, 2015, memory demand has been down significantly, and data center guys told us that why, I asked them, why? Memory demand has been down significantly in 2015? They are saying, we did optimization, we did optimization. Means that, hyper-scalers, they build their own computing servers in their own, scale out and they optimize that one by adapting the most advanced software technique. And that time, memory industry has been down. I study about the data center since the year 2015.

What is the memory consumption a lot from this data center? Maybe a lot of memory consumption is going to be in data center. And what they are doing before 2016, they have -- they tried to have the most advanced -- they developed the most advanced technology, most advanced computing architecture. They want to try to find out what kind of services to deploy to the market, then we hit the market, and we earn the money a lot from our customer services.

They realized that we need to build our own data center by adapting the most advanced technology and, yes, we call it, yes, infrastructure as a service plus platform as a service. They build many kind of services on their own. And then they realized that, oh, I have regular resources to support this kind of stuff. And they deploy IaaS and PaaS to the public and they promote that IaaS and PaaS to their customer, and then customer start interesting to join data center. All the customers, their customers is very nervous about to move their data, own data to public cloud. So they are thinking, okay, I understand that the benefit what we own by using data center. However, they have to keep their own secret information in their own.

That's why there is a 2 track for data center deployment business is, one track is on-premise, strongly rely on all the information rely on the data center, although one is the big company, they want to keep their own data in their own and also normal data has to transfer to public cloud. We call it hybrid cloud.

So right now, we are very early stage of data center business at this moment. What is going to be the next? Still very high gross potential for the data center from dot-com and Fortune 100 -- Fortune 500 companies try to move their data to public cloud, so Amazon, you may heard about Amazon's Snowmobile. They are providing some snowmobile services to their customer. They visit their customer. They download all the information from their server to snowmobile and then they dump that on the Amazon data center. So that things happen. So a lot of momentum to grow.

And on top of that, the more important thing, I already mentioned before, 5G. 5G may impact this data center a lot. I already mentioned before, 5G infrastructure provides hyper-connectivity, means that, all device connected to each other and then they generate a bunch of, bunch of amount of data has been generated by those gadgets.

And techno company point of view, they have some new services they're looking for. Net neutrality, you already heard about in the United States.

And they have their own business like Amazon, like Microsoft. And this 5G infrastructure, the base station, the core part and actually part is going to be because 5G follows the market, and the real-time communication is very critical. When you drive autonomous car in the road and then there is no real-time communication, in that case human life is going to be terminated because of the missed communication, missed information and delayed information very, very critical impact to the business.

And the lastly, autonomous car company. Autonomous car's era started, I don't know when the autonomous car era level 2 is started, I don't know actually. And if one step, autonomous car started, bunch of, bunch of information, very critical human being lives, critical information is going to be treated in real time.

And also, auto manufacturer, they also try to have their own data center to have their own services for their customer. They are not -- they don't want to rely on Big Data Center guy. If they give their data to data center, then that information has to be analyzed by them and then they could make some other services for the data -- other services for the automotive market. So they try to keep their own data center by utilizing their own data center and then they want to services to the market for their customer.

So I could really say today, data center market is just started, is just started.

Okay, from here, as I'll touch more detail about the data center, what is the biggest enabler to grow this data center market for the memory point of view.

Any other questions? Because after my presentation, you guys need to go to have lunch. When I was in military service and when I was a student in university, I don't like professor in longer lecture just before lunch time. But I already spent 20 minutes, but I have bunch of slides. Only I prepared 20 slides here, only I have 27 minutes 50 seconds. Okay, let me start here.

Data center beyond 2018. The biggest enabler of data center is AI and in-memory, but you can recognize in-memory means that in-memory database, the stand in-memory that leading company SAP HANA. This 5G already mentioned before, 5G provides hyper-connectivity and high bandwidth that enables IoT easily. And means that, there were bunch of, bunch of information structured, unstructured data is gathering to some places, that is data center because data center handles this data as a value and immediately they have to treat this one and then they have to response this information to their customer, their client to give them some other opportunities.

So as you can see here, data created and stored exponentially grows, that is, the data is very, very important in this data center guy.

Let me start AI. When I firstly listened this AI, oh, AI is going to be the very good application to consume more memory. When you look back a long time before, the AI machine learning algorithm already exist. Why? The long time before, AI, machine learning is not popular to all of the – this audience today. Even I didn't know about the AI back to 2015. My colleague traveled to United

States. In 2015, I traveled to United States in May time frame and together what the memory demand is going to be. And we promoted SSD to the market aggressively. And October time frame, I needed to go to United States together for surveying the market, with our -- the engineer and one engineer after travel, he called me, "hey, Sewon, you know what happened compared to last May time frame when you visit and when I visited this time frame October. Everybody talk about the AI and machine learning." I started to study about AI and machine learning. That time frame, nobody knows NVIDIA what he is doing. They launched DGX-1 to the market and what this DGX-1 is going to be. And our product training guy, fortunately, they already knew about some kind of high-density memory requires certain time frame and that time frame is just from -- for our product training to marketing and I handle HBM memory.

I realized that. Wow, this DGX-1, the HBM is critical role in this DGX-1 machine. After that, I studied about AI a lot, the machine learning. What is the machine learning? And I have some questions because I'm not an engineer. Why -- the AI, machine learning algorithm already existed. Why these densities are just now popular? Everybody talk about the AI and machine learning. And that time frame -- people in that time frame computing power limited and so algorithm existed, but computing power is not enough to support them. Machine learning is critical one is to how fast they get the conclusion. And what happened after that? What happened? CPU power is getting upgraded by applying there Moore's law. And – but one specific machine learning area, engineer was looking for some other accelerator, some additional, something to power their need. When you look at long time before, when you use that -- when you buy a PC and you are the gamer, in that case, normal graphic engine inside the CPU is not enough to support the requirement. The same story happened to this AI.

So all the engineers are looking for some other accelerator to enhance how could they reduce machine learning algorithm as quickly as possible, efficiently they could get the result based on that.

Finally, they found their one GPGPU. Right now, that's why NVIDIA is -- I need to buy NVIDIA stuff long time before. Unfortunately, I didn't know at that time

frame and I said to my son, he is in United States. When you earn the money, when you get the money, please buy some stock. Anyhow, just kidding.

And GPGPU is the main role at the moment. This is revenue-wise, but in the future, this is very expensive solution, but very powerful. However, all the engineers and data center guys are looking for some alternative choice for replacing the expensive GPGPU solution and, finally, they have FPGA and ASIC. This FPGA and ASIC is not only for the machine learning area. Data center guy, the infrastructure, it consists of network fabric and computing fabric and storage fabric. There is some limitation of natural bandwidth. So how could they enhance effectively network bandwidth, that is their core competition, that's why they are looking for some FPGA and ASIC solution. Google, ASIC stand -- TPU, TensorFlow is kind of ASIC, and FPGA is programmable. Based on their work load, they could change, they could modify that one, so FPGA business here and ASIC. As you know, the FPGA has more faster growth than ASIC. You can follow me. My pronunciation is too difficult to understand. My parent was a teacher.

My parent wanted to be, my son is going to be a professor, but my parent was the elementary school teacher. But my parent insisted me, you have to be a professor in the university, but I failed. And I asked my son, you are my son, you have to be a professor, but once again my son also failed.

Okay, just kidding. You can follow me. I have 20 minute right now from now on. I have right now, all half of them is finished. So what is the revenue growth for this AI application -- machine learning application? Cloud service providers are expanding AI's service rapidly.

The data center business is just starting, but this AI business is kind of infant stage, infant stage. When you look at here, we are here, very small revenue. AI had their revenue here. And this USD 115 billion up until 2025, among that cloud is the core of rule of AI hardware, 40x bigger than year 2017.

And AI service revenue point of view, all the area when we face every day, for example, health care, advertising, automotive, retail, energy, sports, you remember in CS, Intel announced some AI functionality, their Nervana system, and the United States basketball and NFL, National Football, is very popular in

the country. When I was in the United States, I was a big fan of basketball. The football, they analyzed all the guys moving and everything, they analyze for that. And that's why AI service revenue is going to be exponentially growth '17 here and 2025, 20x revenue growth.

All area, AI is aiming for all area, not for health care, not for retail, not for legal, logistics, gas, all area of the human being is touched, they are looking for -- they are cultivating new business model for this AI. That's why this AI is very, very important role for the data center guy.

The value of data center, data is changing. As you can see here, time variable, analyze data and real-time data era is going to be started. We are here and a bunch of amount of data exponentially grows here. And traditionally, data era, data is just a data. But from now on, the data is handled by real-time data is the money. Data is the money. You cannot imagine how much important the data. This graph shows you the time value of analyzed data. But data itself is meaningless. Time value of analyzed data. Data has to be analyzed to get the value and when the data analyzed as a value, very early stage of that, the money is bigger than ever. But time passed by the data value, analyzed data value is going to be diminished.

So mission-critical data here, real-time data has to be handled immediately. We call it mission-critical data, that makes the money a lot. That's why the value of data is changing, very important. But fortunately, you are typing the keyboard right now, you are sending e-mail to your colleague or your boss, oh, that guy is -- that guy is explaining data center, but he's right or wrong, please check it out. But data goes to wherever you generate the data, that goes to the data center.

Data center is watching you, surveillance camera. They are watching you. Whenever you go to the other place, and then [inaudible] you have a cellular phone here and a smartphone here, they knew S. W. Chun is in Singapore. Oh, told you, it was 1984, is already starting.

And the important thing is that 5G, I many times emphasized 5G and autonomous car era. 5G is very important for us. Autonomous car more, more important for us. Autonomous and 5G important to telco company and data center guy, but autonomous car is especially important in memory side. Why?

Autonomous car started in the car, you are watching TV, you are watching video clips, whatever, but the data is real time transferred to your car and car has to receive very -- the most updated one. And you're going to be dead because of the latency. When you go through the road, but there is a block, big block there, accident happened, but you don't know because you don't watch outside of the car, and but that data is immediately transferred to your car and then there is a block, you have to stop, but there is latency issue, a little bit delay that information to the car and then the car crash, so very important. And also, the quality and performance is very, very critical for autonomous car era started for the memory point of view. And semiconductor point of view, very important.

And why I am emphasizing data -- exponential growth of data because the data has to be treated real time and otherwise the data is not valuable.

So this is one of a good example, the SAP HANA based one, the goal -- that this guy's goal is to convert 100% of SAP product to SAP HANA based by 2025. SAP HANA base means that in-memory database system, means that all the data dumped to DRAM side and that is handled in DRAM because DRAM is the fast latency they have and provide high bandwidth too, that's why they're looking for DRAM solution for that one. So this in memory is very, very memory DRAM intensive application. By 2025, all the -- their goal is all the product is going to be the SAP HANA in-memory DB system, means that they need more DRAM. And also DRAM, the calculation of the DRAM and then that has to store to hard disk driver. Nowadays, they are using hard disk driver and SSD based on the work load. But in the end, latency, I already mentioned before, latency is very important to handle the valuable information and then it goes to hard -- HD to SSD. The SSD portion is getting bigger and bigger as time pass by.

Okay, so when this all phenomena, AI and in-memory database for the server area in data center area, I calculate that one to -- I convert that one to our memory business. 2018, AI and in-memory database portion is very small at the moment. That's why I'm saying, data center business is just started for the memory consumption point of view. And 2023, AI and in-memory portion, in server memory, total revenue is going to be huge portion. That's why data center guys are focusing to AI and in-memory database. In other words, in-memory database, business intelligence recorded. So that's why they need

more high-capacity, fast latency, high-performance DRAM solutions they need, also they're looking for some very fast latency SSD, they're looking for because of this reason.

And I express in other expression for worldwide memory revenue by application. We are here now. Server portion is going to be here. And 2023, server is going to be the main role for memory business industry.

Now mobile smartphone area is the main driver for consuming the memory, but in the future, server is going to be the main role for consuming memory.

This is the conclusion slide. You can follow all the stuffs, today I explained to you. Shawn -- Shawn Kim, you follow me? Why I knew your name. Already you report. Okay, let me drink water. This is very familiar, the name only Nicholas, when I was sitting in the IR, question -- Nicholas, blah, blah, blah.

So this is the first time to face-to-face meeting, I'm very happy to be here to make this kind of presentation. This make you happy, this presentation may help you to understand the memory business in the future from now on. So this is the conclusion page.

Data center is at the center. When this all -- I already explained the public cloud, hybrid cloud, AR and VR, SAP in-memory database, AI, 5G, edge computing, IoT, all the information, they generate multiple application, they generate bunch of, bunch of data that goes to data center.

And the more important thing is that, it's kind of a snowball effect, snowball effect. Long time before, one application demand has been down and then that application is only impact. Based on my analysis, all demand is connected, all demand is connected. Once one demand is picking up and that influences the other area and then kind of it's a snowball effect. Memory demand is getting more and more. But on the negative side, down significantly and negatively in fact to the market. But based on today's presentation, for the data center, the high growth potential AI and in-memory DB to [inaudible] already explained. If my guess is right, in that case, memory business is not so gloomy. I cannot say, not so bright, but anyhow, high growth potential, I could anticipate. So all demand is connected. I'd like to emphasize this message to you.

Okay, any other questions by here? Because on the next page, I'll explain about the Samsung strategy, how could we react based on this big business opportunity, what is the Samsung strategy from now on? You can follow me. Thank you very much.

Let me start the Samsung solutions for data center era. Okay, this is the kind of a snapshot. Conceptual data flow in data center. This is not – this is not only the engineering section, this is kind of IR section. You need to understand what is the data flow in data center. Where is the memory requirement, where is the opportunity from memory business point of view.

Here, I heard about the data scientist, data scientist. Oh, yes, one small joke. My son studied in United States and he asked me a question, "dad, I'm going to have a major in university." What major is better? I recommended him, "okay, computer science. It's the future of your life." And my son selected computer science. And then I listened that one from my son, data scientist. That is the very, very first time, data scientist. What data scientist is doing? This data scientist in archive, for example, hard disk driver. There are a bunch of, bunch of big data exist. All the data generated only 10%, 5%, I don't know, but only valuable data has to be stored to archive. And then these data centers -- data scientists, they're looking for some business by mining -- data mining from the big data lake. They try to find out some other business model based on that. And then they find out some good business model from the data archive. Data lake, recorded data lake and then they're mining the data and then that is stored to be treated, handled the meaningless data to valuable data.

And the video clip, surveillance camera information stored here, that is the recorded unstructured data. That transformed structure the data and then to be treated in computing system here. And you well know about the Von Neumann computing architecture. I was an engineer for a long time before. I had been an engineer for 12 years in Samsung. I started my job in Samsung as an assembly engineer. At that time, DIP PLCC package I developed. I was a process engineer. And then I moved to the product engineer, kind of analyzed the yield and how could we improve the yield, how could we make qualification and then I moved to the product planning. And finally, right now, I moved to the sales and marketing.

And that time, I told the sales and marketing guy as a product planning guy, formally mined computing architecture here. And CPU requires memory and this is the DRAM and storage, SSD or HDD. And I already mentioned before accelerator here. Long time before, the accelerator was just the graphic card, but nowadays, graphic card has a different role for machine learning area and accelerator here. Accelerator goes to kind of GPGPU and TensorFlow and FPGA or whatever. And this computing system calculate that one and then finally data scientist find some services, okay.

This services is good for our business. And then that deployed to the services from data center guy. What it means to us, memory point of view, what it means to us? We have to provide high-performance product and high-density, low-latency product with very high quality of product we have to provide to our customer and if there is no HBM and the machine learning, it takes a long time than before. But Samsung is the first company to provide HBM to the market. Now we have a huge market share for that and that helps a lot to develop many kind of AI by utilizing AI and machine learning, and they found some services to their customer.

So memory role is getting critical in the future, what is the memory solution in Samsung? No matter what, we are not negotiating quality, that is the base of Samsung strategy for memory business. Quality is the key because the DRAM side, I already mentioned that in-memory database, all data has to be handled in DRAM side and there is one single bit error, system crashed. Our customers are looking for very high quality of DRAM, and we have to provide. We have a responsibility to support that one.

High-performance point of view, Samsung developed HBM, world's first, and then we launched this product to the market. And nowadays, this demand has been skyrocketing at the moment. They're looking for more and more HBM memory, but the issue is that HBM is expensive. And that's why, we -- our product planning guy recommended me, okay, the GPGPU can use HBM if their work load is so critical and very important has to be handled very quickly, then use HBM. And otherwise, the more lower bandwidth GD6 and otherwise there, they have no money and they have to looking for some machine learning

solutions and then they -- we could provide GD5, but those 3 products, very robust solution has to be.

The machine learning, the system, very power-consuming product, a lot of power consumed by AI machine, machine learning. And already I mentioned 5G or whatever, low latency is very potential, storage area as well. DRAM definitely very fast latency we have and we developed very low-latency product, we call it Z-SSD, very low latency. And also, I already mentioned, in-memory database requires high-density, 256 gigabytes, 128 and 64 gigabytes and SSD like this. And we provide -- I do not want to touch about detail in NF1. What is the NF1? That's the form factor to provide a very high capacity of SSD.

Let me touch what is the Samsung, the technology leadership. Our engineer understand the limitation of planar NAND. And then, internally, we discussed about what is the next step if there is no migration for the planar and there is a technology barrier in the case what is the break-through technology long time before. And then our engineer take risk. Okay, let's move to the V-NAND. That time frame, even S.W. stupid and white, this guy didn't trust our engineers' decision, while we have to put the wafers with that planar NAND and we earn the money. However, we have to take risk. We are the leader in this industry. We have to break through technology, we have to show to the market. And then we decided goes to the V-NAND here. And look back year 2010, that time frame D1X/Y/Z DRAM technology was getting difficult and more tough and tough. But I'm very proud of Samsung engineer. They showed me this clear road map. So I dearly say, Samsung -- in-memory business point of view, Samsung is the technology leadership, still we keep growing. Now we have keep growing that technology leadership continuously. So what is our solution for the AI acceleration? I already mentioned many times, HBM, GD6 and GD5. Memory performance equals AI performance, and we keep providing the high-bandwidth memory, and we keep providing GD6, very high-bandwidth memory continuously and GD5, based on our customer's choice. So we line up not only HBM, but also GD6 and GD5 to this AI acceleration. High-density solution, Intel Skylake, 2 CPU based one 6-channel, 2D per channel, Samsung is only one company to provide over 3 terabyte because we developed a 16-gigabit mono DDR4, world's first 1.5 years before than our competition, and we strongly

promote this product to the market. And in the case, high capacity of SSD, we keep provide to our customer. So world's first product is this.

Only the time clock is stopped. I have to finish my presentation today. And what is the very strong point for the -- we could say to the market, Samsung has a leadership for the memory industry because Samsung is not only component provider, Samsung is the total solution provider, means that, we rapidly goes to market than the other. Why? We have all solutions. The vertical integrates to all the things -- vertical integrates, for example, SSD case, we have a controller, we have NAND flash. Inside of that, SSD, there has to have some DRAM and many package technology we have to provide for our customer. So Samsung is only one company to have a total solution and go-to-market rapidly than the others. That's why, Samsung is the #1 in the world.

Okay, let me -- I have only 2 slides, you must be hungry, and I explained all the stuffs. If I deliver my message properly, then there is no question today. Okay, what is the Samsung memory's mission? Already I mentioned that, AI and in-memory database. Here, left slide is human being and in the long term, AI and machine learning has been done properly and then some robot is going to be taken over some time frame. And what's Samsung memory's mission from now on? Samsung memory is going to be the bridge between human being and AI robot. Why? Think about that. Robot, I watched Eagle Eye, I watched the movie, I have very, very impressed, because Eagle Eye is kind of AI, total control system in United States. They watch all the stuff, all the stuffs, but to destroy their AI system because they tried to destroy some issues and then the guy tried to extract from their system the memory. If they don't have a memory, in that case, that very sophisticated AI system is meaningless, if there is no memory.

So through technology revolution, we are bridging between human and AI robot.

This is going to be the last one. Samsung keep providing leading-edge technology for our customer. By utilizing that Samsung memory, our customers provide their customer, means that their society and that make this industry healthy and our human being life is getting more easier, getting more happier.

So Samsung mission statement is to devote its talent and technology to creating superior products and services that contribute to better global society.

This is end of my presentation. And you guys must be hungry. I'm also be hungry. So if I explain about my presentation agenda properly, then there is no question. Let's go to have a dinner -- or lunch, please.

Okay. Let me stop here my presentation today. Thanks for listening my presentation. And -- but this scenario is right or wrong, maybe 2 years, 10 years after, you may realize that one. And I hope you -- this is going to help you to understand the market. Thank you very much.