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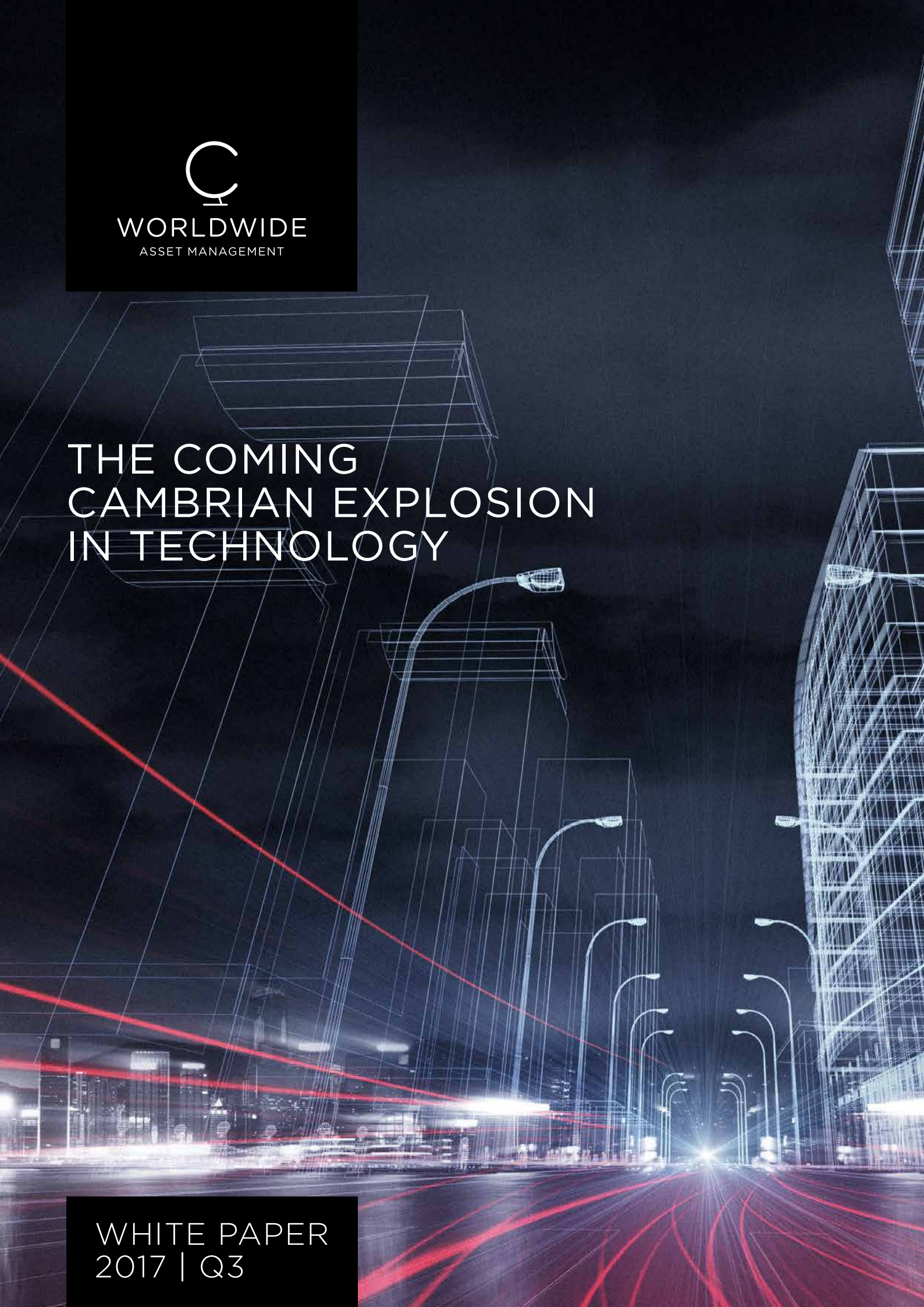
THE COMING CAMBRIAN EXPLOSION IN TECHNOLOGY



WHITE PAPER
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The coming Cambrian explosion in technology

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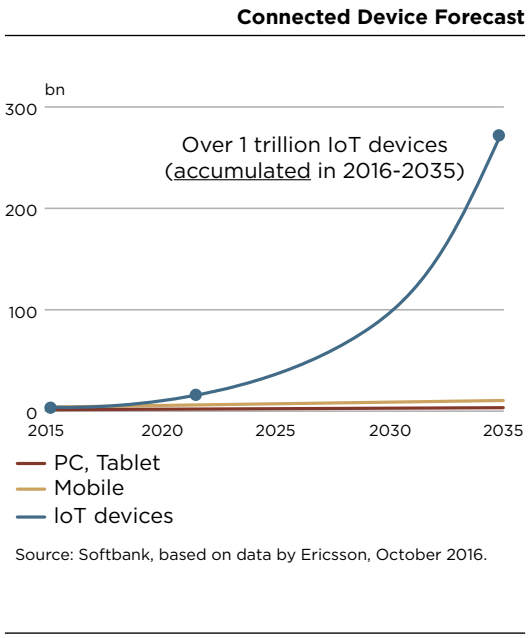
Over the last few years we have written several white papers on the advancement in technology, as we think something unique is unfolding. Building on the early IT revolution of the 1990s and the mobile and smartphone revolution in the 2000s we are now living through another critical inflection point. The combined forces of maturation of Moore's Law and the acceleration of computing power, data storage, communication networks, and digital platforms are now powerful enough to build on each other and the gains can compound exponentially.

In 2016 Masayoshi Son, the chairman and CEO of SoftBank Group painted a very visionary picture of the period we are going through by comparing the emergence of the Internet of Things (IoT) to the historic period 542 million years ago, when the first more sophisticated animal life appeared on Earth, a period termed the Cambrian Explosion. According to a definition by The McKinsey Global Institute, the term, Internet of Things, broadly encompasses a class of devices that 'can monitor their environment, report their status, receive instructions and even take action based on the information they receive'.

Prior to the Cambrian explosion, most organisms were simple, composed of individual cells occasionally organized into colonies. Over the following brief - in geological terms - period of 70 to 80 million years, the rate of diversification accelerated by an order of magnitude and the diversity of life began to resemble that of today (Wikipedia, 2017). Mr. Son argue we are at the edge of a Cambrian explosion in machine utility and explains this development by pointing to the Andrew Parker theory, that the arrival of vision for living organisms drove the acceleration of evolution of diversity on our planet. Similarly, according to Son, IoT and machine vision will drive a "Cambrian explosion" of technologies that will transform cultures, prolong and improve lives and make people happier.

"The Cambrian explosion and the IoT explosion are basically the same thing," Son said. In technology, the evolution from the PC as the center of gravity, to mobile and then the IoT is quickening to the point where we will leap from billions of deployed IoT devices today to 1 trillion devices by 2035. The devices will transform healthcare, infrastructure and the way data is channeled and used to improve lives. Once all those sensors or "eyes" begin to perceive and capture data from the world around them, the real work and value creation begins. In the modern world as the number of sensors explodes, so too does the amount of data we receive. Analysis of this data will give us intelligence, and this deep learning will make us super smart, Son said.

Figure 1:



While it sounds extreme to expect 1 trillion IoT connections within 20 years, one thing is for sure, and that is that the number of connected devices will explode in the coming years. Some of the largest verticals for IoT will be in automotive. In the long-term all cars, trucks and buses will be connected. In the EU this will be driven initially by the eCall automotive directive, which requires all vehicles to be capable of automatically calling emergency services with GPS coordinates when the airbags are deployed. Real time traffic alerts and route optimization of car navigation will likely further drive adoption. Parallel to this development is the move towards more and more active driver assist systems in cars which will eventually take us to the fully autonomous car, which basically will be a robot equipped with a high number of IoT devices.

Another large end market is the "Smart cities" infrastructure like Smart gas and electricity meters, traffic monitors, parking space monitors, smart traffic signals and security video surveillance cameras. Other very large end markets will be within Health

where many sophisticated devices are being developed to help doctors monitor and manage chronic diseases like cardiovascular conditions, diabetes and hypertension. These devices can also monitor falls by the elderly or track the location of dementia sufferers. As society ages, we expect there will be an increasing number of health focused 'wearable' tech, which will assist doctors in managing patients and helping them to maintain independent living for longer periods of time.

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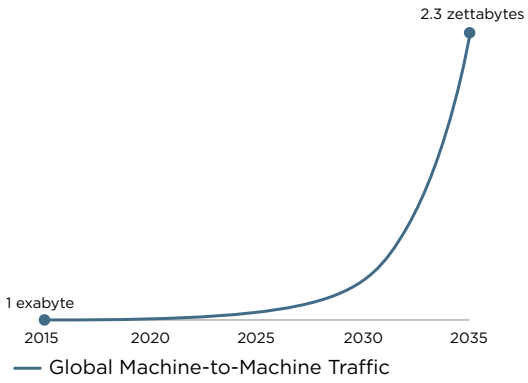
Figure 2: IoT Data Traffic per Month



Source: Softbank, based on data by Cisco & Ericsson, October 2016.

In industry, Intelligent manufacturing is a key area for future IoT applications. Intelligent devices such as sensors, measuring instruments, industrial control systems and motors and robots are used in the manufacturing process. By connecting devices within each site as well as sites across various locations, intelligent control can be achieved to improve productivity, save energy, eliminate waste, improve client management and promote integration of the business. Predictive maintenance is already today a major focus area for companies but will see further growth as more IoT enabled capital goods get deployed in the coming years, and promises large improvements in total cost of ownership as well as productivity improvements. While impossible to predict with any form of accuracy the amount of data generated by the growth of IoT in the years ahead it is fair to say growth will be extreme. Already today the doubling rate of all historical data is about 9-12 months, and most likely that doubling time will be reduced in the years ahead.

Distributed AI is accelerated by the Cambrian Explosion

In previous white papers we have written about cloud computing and AI and argued that AI today is accelerating due to three factors, namely more powerful chips, better understanding of neural networks and the explosion in data on which the neural networks can be trained. As AI improves more value can be extracted from the data, and as data gets more valuable there will be a desire for ever more data creating a virtuous cycle of more data and better AI. The Cambrian explosion of IoT will accelerate the development of AI because of the explosion in data and the need to extract value from the data.

Until today we have thought of this evolution of AI happening centrally in the cloud. But as IoT develops there will be a need to also develop AI at the edge of the system. AI will develop from a centralized system to a distributed system, where individual IoT devices will have their own intelligence. The training of the deep neural networks will continue to happen in the Cloud but the ongoing inference of data will happen at the edge. This will have profound effects on the future demand for silicon.

This is because with sensors, the generation of data is decentralizing, accelerating, and, combined with artificial intelligence, calls for more local computations. According to Bernstein, sensor shipments have accelerated last year from 6% to 12% year-on-year growth (Ferragu, May 2017). Sensors are popping up everywhere and they are improving in quality and growing in diversity at an unabated pace. With more sensors comes more data generated at the edge, which first makes it increasingly difficult to centralize all of the processing of this data, and second, drives the emergence of use cases where a permanent back and forth with the cloud is not an option anymore. Today we can bear with waiting a few seconds

before Alexa or Siri responds to our questions, but our car will need to decide pretty instantaneously whether there is a hazard ahead of us. Autonomous driving is the most immediate example of sensors driving the return of processing to the edge. Augmented reality, robotics, digital health, retail, etc. will come right after.

We see an evolution towards a two-tiered architecture where local specific learning and inference collaborate with centralized generic learning.

Who will capture the value creation of the Cambrian explosion of IoT?

The winners from the communications and mobility revolutions over the last 20 years have been internet companies like Alphabet, Facebook, Amazon, Baidu, Tencent, Alibaba and technology companies like Apple, and — at the margin —Samsung and TSMC. The secrets to become a successful company have been low capital intensity, low or zero customer acquisition cost, and a "winner take all" platform market structure. No doubt many of these winners have made life easier for their users, but the question of whether these companies were truly creating value, or simply capturing it, has been secondary.

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Based on the lessons of the last two decades, it is fair to consider whether looking at companies that are doing revolutionary things with IoT and AI is the right approach. It might border on heresy but it can be argued that the last decade's most successful companies contributed very little to the advancement of technology but instead by doing very intelligent business model innovation utilized others inventions to their own advantage. The early internet revolution of the 1990s was a result of the work of tech companies like Nokia, Ericsson, Lucent, Cisco etc. and huge investments done by the telecom operators building out their networks. These companies derived very little lasting value out of their efforts. Instead the value was captured by platform companies that could piggy back on the technological progression done by others, and make life easier for their users and being rewarded for it.

A fair amount of time could be spent talking about the value chain of IoT because it is such a broad area, covering component manufacturers, connectivity providers, platforms and service providers.

We have to consider whether the Internet companies could — again — extract all value from this new wave of technological progression, or whether the companies actually developing these new revolutionary technologies also will benefit. In a follow-up white paper we will expand on the internet platforms ability to continue to dominate the profit-pool. The current focus will be on where we see the value creation amongst the technology companies.

The shortcut we allow ourselves is to assume that the operators being responsible for the connectivity of the system continue to be squeezed between customer service demand and a lack of pricing power and therefore a continuous inability to extract long term value from the explosion in IoT and Data. This will most likely continue to be the case as long as net neutrality is the basic regulatory premise – i.e. that operators cannot differentiate services to different customers or data types.

From cyclical growth to secular growth in semiconductors

It is our contention that there today is a unique opportunity in a specific part of the value chain, namely the companies focused on developing the semiconductor chips that will drive the technological Cambrian explosion. Historically the value opportunity in semiconductors, although on a secular long term upturn, has been highly cyclical and very capital intensive, a combination that's basically the opposite of what has made the Internet giants such fantastic investment opportunities over that last 20 years, namely secular growth and low capital intensity. We believe there is a change in the drivers of the semiconductor cycle. Historically there would only be one or very few drivers of the semiconductor cycle, in 1980-2000 the PC cycle but not much

else, and as the PC sales flattened out first mobile phones and from 2007 and onwards smartphones have been responsible for the bulk of the growth in semiconductor sales. Looking forward, this will change dramatically. There will be many independent cycles driving the semiconductor cycle, and cyclicality will fall and instead we will experience secular growth and higher growth than what we have seen for many years.

Drivers of Silicon Demand:

- Training of neural networks

As we get further and further into the virtuous cycle of more data and more AI there will be a steep increase in the demand for computive power in the data center. The data center is where the deep neural networks get optimized – trained – on enormous amounts of data. Google was probably the first company to train a deep neural network on massive amounts of data when they in 2012 "taught" the computer to recognize cats in videos on YouTube. According to Bernstein, the network Google developed was about 1 bn. neurons and trained on 10 mio. frames from Youtube videos (Ferragu, May 2017). The training exercise occupied 16,000 server cores for three days similar to 16,000 high performance laptops. This example shows a couple of things; firstly, as we have stated previously in another white paper, that AI learning is a game for the big cloud companies, because you need to have control of an extreme computive power and loads of data in order to do big scale AI training. Secondarily, training AI is a game changer for the need for semiconductors. More and more powerful parallel processing chips will be required, driving an overall acceleration in silicon demand.

- Inference

However, training of neural networks is only the tip of the iceberg when it comes to the computive demand from AI. Inference, that is the use of trained networks on new data, is probably multiple times larger in terms on computive demand. The usage of AI inference grows with the number of users and the frequency by which the application is used. Today we have many mass-market applications of AI where the number of users is counted by the millions and sometimes billions. An example is Google Translate. Google has developed its own chips for AI Inference, called the Tensor Processing Unit, to be used instead of Nvidia's Graphical Processing Units. Google has said that without development of specialized chips for inference learning, voice recognition inference generated by all Android users speaking to their phone only for 5 minutes a day would have required Google to double their data center capacity.

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As things are today it is very easy to expect very rapid growth in demand for advanced semiconductors in datacenters but also very difficult to identify the winning companies, because technology is evolving rapidly and the technology roadmap is – to us – unknown. Many different types of advanced parallel processing chips like Tensor Processing Units, Graphics Processing Units, Application Specific Integrated Circuits etc. are being advocated but as we see it today no clear winner is visible. Only that no matter who wins, the demand for silicon goes up as AI advances more and more.

- Edge computing

With sensors the generation of data is decentralizing, accelerating and combined with AI calls for more local computive power.

TRAINING VS INFERENCE AI:

Working with deep neural networks is a two-stage process: First, a neural network is trained: its parameters are determined using labeled examples of inputs and desired output. Then, the network is deployed to run inference, using its previously trained parameters to classify, recognize and process unknown inputs.
Source: Nvidia

Increasingly, it will be more and more difficult to bring all this locally generated data back to the data center to be analyzed. Instead, more and more AI applications will be exercised locally, demanding high compute and low power demand semiconductor chips. As the auto industry evolves towards an electric vehicle platform, the electronic content of cars will rise rapidly, especially in the form of semiconductors. Furthermore, the parallel trend towards Autonomous driving is the immediate example where it will be mission critical that the data treatment is done with no latency, which calls for local data analysis. Augmented reality is another example as well as robotics, health care and retailing. As more and more data generated at the edge becomes valuable so does the need to have computive power at the edge. This will be another and potentially bigger driver of demand for silicon.

- Industrial IoT

Industrial IoT (IIoT) has generated much excitement, but we are still very early in the development of this exciting concept and think it will take some years before it becomes mainstream. However, one area within IIoT is strongly accelerating today, namely Vision. Vision technologies are an enabling technology for the IIoT. It is, in our view, one of the most concrete investment opportunities from this megatrend in the coming years, and an area where it is possible to make focused investments in high quality companies today. Vision products, i.e. laser sensors and camera systems enable machines to see. They automate, provide robotic guiding, assembly alignment, precision material processing, and tracking of moving assets in factories and warehouses. These products improve production efficiency and quality, and are important enablers for the IIoT.

For the machine there are two ways to "see," and hence, two major segments of the industry, namely Machine Vision, where a camera takes a picture, which is analyzed by software, and another approach called Vision and Laser Sensors, using lasers and sensors to detect.

These technologies will give vision to the machines and make the prediction by Masayoshi Son of a Cambrian Explosion in Technology a reality.

We draw two conclusions from the growth of Machine Vision; first, that this is yet another driver of Data growth and therefore the need for computive power and silicon. Second, that the Machine Vision market is characterized by high growth and very high profitability both for the enablers and the users of Vision Technologies. It is said that the cost of vision technologies is perhaps only 1-3% of the annual capex of the plant and the payback time for machine vision investments is as short as 6 months, and at the same time the leading players like Keyence operate with operating margins above 50% and return on invested capital above 100% (Bernstein, July 2017).

Conclusion

We are on the brink of a veritable Cambrian explosion of combinatorial innovation, catalyzed by the confluence of cloud computing, mobile connectivity, automation and artificial intelligence. There is no way to quantify or prove this statement, but we are firm believers the world will see more technological acceleration and development the next 5 years than what we have seen the last 20. As Kevin Kelly, founder of Wired Magazine has formulated it: "... the next 20 years are going to make this last 20 years just pale. We're just at the beginning of the beginning of all these kind of changes. There's a sense that all the big things have happened, but relatively speaking, nothing big has happened yet'".

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Conceptually, as a concentrated active investor you have to feel great about this, since the technological acceleration must also be associated with more creative destruction, since companies that don't embrace the technological acceleration will perish and resources hopefully will be better allocated to companies that can thrive in an environment characterized by faster and faster change.

More specifically, we find many interesting investment opportunities from this technological acceleration. The current environment is very positive for the big cloud companies, for reasons explained earlier in our white paper about cloud computing. We find the whole value chain of semiconductors

exciting. However, due to uncertainty about who will be the long term winning chip designhouses, our current focus is on the beginning and the end of the semiconductor value chain. That is, we like the very few intellectual property owners of semiconductor chip designs. Furthermore, we like the final manufacturers of the chips, the so-called foundries, who do the actual production of semiconductors, as these companies are dependent on the actual growth in semiconductors but not in who of the manufactures actually thrives. We believe, as stated above, that growth will be less cyclical and more structural in the future and therefore expect both earnings growth as well as multiple expansion in the years ahead for the leading companies in this space.

Last, it will be more important than ever to emphasize de-selection as much as stock picking in the years ahead, as the technological acceleration makes its inroads into old business models and eventually reveals the dangers of passive investment styles and index tracking.

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