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MACHINE INTELLIGENCE:

THE 'KILLER APP' FOR THE DIGITAL ECONOMY

ALAN W. BROWN AND ROGER CAMRASS

REFERENCE PAPER

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EXECUTIVE SUMMARY

Information has always been at the heart of decision making. Over the last half-century we have harnessed the power of data by introducing game-changing administrative systems for tasks such Customer Relationship Management (CRM), Supply Chain Management (SCM), Human Resource Management (HRM), and Enterprise Resource Planning (ERP). Thanks to maturing Internet-based technologies, these "back office" systems have migrated -- increasingly reaching out into "front office" activities so that end users, in real-time, can monitor production processes, view current order delivery status, engage in consumer collaboration, and so on. Today, we as employees, citizens, and consumers can depend on the power of the Internet-based systems to help us make more meaningful decisions about every aspect of our lives.

But despite the massive technological advances in interconnectivity, computer processing, and storage, the analysis required to improve the quality of our decisions has not reached its full potential at any level of society. For example, a recent study of over 5,000 employees in 22 global organizations concluded that "investments in analytics can be useless, even harmful, unless employees can incorporate that data into complex decision making". Our individual lives are overwhelmed by choice, but we are far away from achieving true self-actualisation.

In this report we identify the missing link between a surfeit of information on every aspect of our economic and personal lives, and an effective means of harnessing an almost limitless data resource. This missing link is called 'Machine Intelligence' or 'MI' and combines a range of technologies such as machine learning, natural language recognition, and artificial intelligence. At its heart, MI offers us sophisticated software algorithms that can undertake non-routine, cognitive tasks to supplement or ultimately replace human intelligence.

We see MI as profoundly transformative -- a central catalyst to deliver the full promise of Industry 4.0 — the coming together of cyber-smart systems, the Internet of Things, and Cloud computing to automate or enhance work activities across the entire manufacturing and services supply chain. Not only will this transform workflow efficiency, it is likely to change the industrial landscape itself, with the prospect of a seamless interlocking of innovative start-ups with the reach and power of traditional incumbents. We as consumers will see similarly far-reaching benefits, in the way products and services are offered to us, thus enhancing our experience in virtually every way.

1 Svetank Shar et al., "Good Data Won't Guarantee Good Decisions", Harvard Business Review, April 2012

IN THIS REPORT WE EXAMINE

Why Machine Intelligence can provide a solution now to the oceans of data in which we are drowning as a consequence of hyper-connectivity and smart devices;

How Machine Intelligence can help automate non-routine, cognitive tasks and thereby transform human experience, enterprises and entire sectors;

Specific examples of how such transformations are generating new sources of value in the digital economy;

The challenges and opportunities for senior executives in harnessing the power of new digital technologies such as Machine Intelligence.

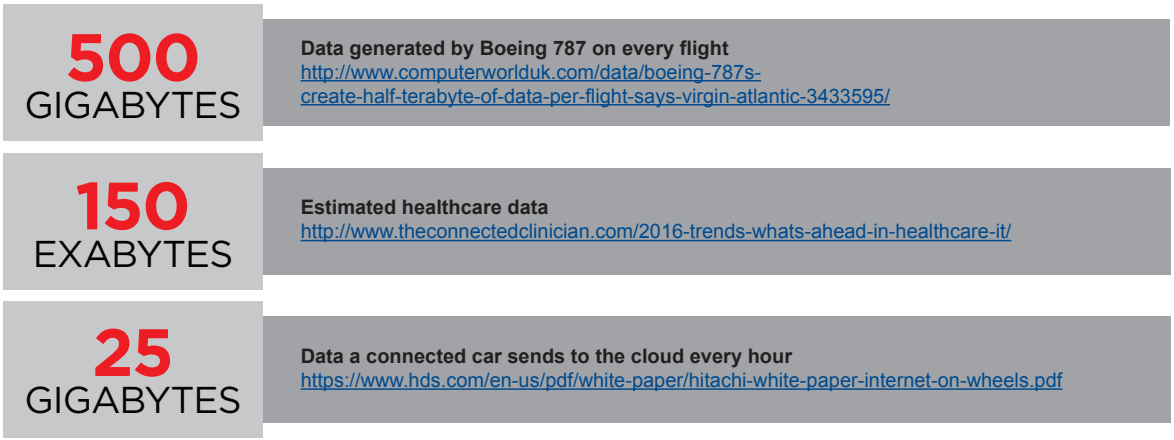
DATA, DATA EVERYWHERE...

With the advent of Cloud based services over the last decade, companies such as Apple, Amazon, Google and Equinix have created vast, interconnected computer utilities across the globe. These are rapidly becoming the information hubs of the digital age. These centres are fed by Exabytes (one billion gigabytes) of data generated by billions of consumers who have benefited from ubiquitous access to services and interaction via a wealth of emerging mobile devices. It is hard to imagine what life was like only a few years ago without 24/7 access to YouTube, Facebook, Google or WhatsApp from every Internet-connected device. Commentators such as Nicholas Carr view the leading companies in the digital economy as "rewiring the world" in a comparable manner to Edison at the turn of the twentieth century[2].

And this journey to hyper-interconnectivity appears to be only in its early stages. Connected Cars, Homes and Cities will change the game again before long, as will the advent of powerful new mobile utilities such as fifth generation mobile infrastructure standards (5G), and software defined networks that can support ever increasing flows of data. Cisco predicts that by 2020, 5 billion people and 50 billion devices will be connected.[3]

How do we harness this explosion of hyper-connected computer power? The vast amounts of data currently generated by the interconnectivity of smart devices, computers and other entities are rapidly overwhelming individuals, communities and businesses. Estimates of the amount and variety of data vary enormously, but the magnitude of this digital landscape is summarized in Figure 1.

Figure 1. Exponential growth of data



These massive amounts of data take many forms, and are transmitted, processed and stored in a wide variety of technologies. Ultimately, however, all this unstructured information is a mere curiosity if we cannot extract patterns, learn from it by assessing what it means, and act upon it by connecting it all together.

We may be in danger of creating so much success with 'big data' and 'open access' that we will be swamped and quite incapable of making sensible decisions. As a result, the current land rush to create and manage data will only be helpful if there is an associated improvement in techniques for understanding and analysing that data in the context of the tasks within which it is being applied. It cannot be assumed that the availability of this data leads automatically to improvements in processes and outcomes. Data is neither knowledge, nor insight, nor judgement. In fact, many studies and observations highlight that larger amounts of data increase the challenges organizations face to act effectively and efficiently in response to that data[4].

2 Nicholas Carr, "The Big Switch: Rewiring the world, from Edison to Google", W.W.Norton&Co, 2013.
3 http://www.cisco.com/c/dam/en_us/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf
4 https://hbr.org/2013/10/does-bigger-data-lead-to-better-decisions

MACHINE INTELLIGENCE IS THE 'KILLER APP' FOR THE DIGITAL ECONOMY

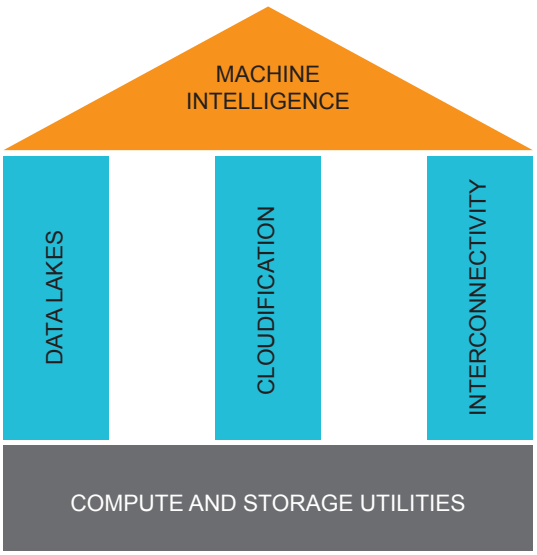
To extract economic and social value from the Exabytes of information now being stored in global information hubs, we as individuals, communities and businesses need to convert this powerful and ever expanding resource into meaningful input that can help us with everyday decisions rather than confuse and overwhelm our lives: Does greater insight into utility usage and smart metering actually improve home comforts? Will the connected car enable us to reduce congestion in cities and avoid accidents? Can banks' knowledge of financial markets be used effectively to advise us on our retirement needs? Do earlier health interventions lead to a longer, more satisfying old age? This is where the value of data lies.

Smarter approaches to data-driven decision-making require significant investment in several important areas of computer science and software engineering. The opportunities to build upon the available data will be lost unless organizations invest in solutions that enable them to bring together multiple data sources, filter out errors in the data, extract meaningful insights from repeated patterns, and so on. Machine Intelligence could well be the integrative mechanism that transforms so much data into genuine sources of new value – the 'killer app' for the digital economy.

The computer industry has a long history of investigation into Artificial Intelligence (AI) approaches, in which computers attempt to mimic human behaviour, and yet progress on intelligent data interpretation and machine learning is still relatively embryonic. Several important developments have opened up the possibility for computers to begin to emulate human cognitive capabilities, as illustrated in Figure 2. Modern day algorithmic software lies at the heart of AI and machine learning. Non-routine, cognitive tasks can now be simulated by such algorithms to help humans to make meaningful decisions in all aspects of their business and social lives.

Machine Intelligence (MI) represents unprecedented potential to make sense of vast volumes of data. It exploits a combination of machine learning and artificial intelligence to yield entirely new sources of value. MI encompasses natural language processing, image recognition, algorithms, and other techniques to extract patterns, assess, learn, connect and act. MI is only now possible because it can build upon core sets of cheap hardware capabilities provided in massive centers that support large-scale data management (Data Lakes), the move to virtualized storage and compute power accessible over the Internet (Cloudification), and managed distribution networks for architecting efficient systems that stitch together all the pieces of these complex systems (Interconnectivity).

Figure 2. The Foundations for Machine Intelligence



A new vocabulary for Machine Intelligence

Discussions in this area are complicated due to the fact that there is no common vocabulary and a set of terms that continues to evolve. Furthermore, common usage of some of these terms changes as new ideas emerge. Here is a broad view of the key terms as used in this report.

Machine Learning
Machine learning is a form of data analysis that creates an evolving model of a problem from the data being analyzed. A set of algorithms is created to process the data with increasing accuracy as the data is classified and assessed. In this sense the computer system is able to learn from data, and is able to gain new insights without being explicitly re-programmed. As pointed out by SAS, by gleaning insights from this data – often in real time – organizations are able to work more efficiently or gain an advantage over competitors in domains such as financial services (fraud detection), government (cyber threat analysis), healthcare (medical diagnosis), and transportation (congestion avoidance).

Big Data
Big data has become the general way in which we now refer to the challenge of a world in which massive amounts of information are generated every day from a broad range of devices: sensors used to gather information in the home, social media interactions, stored digital photos and videos, customer records and online order details, and performance data from instrumented mechanical devices to name a few. IBM highlights the key characteristics of big data in four dimensions: volume (creation and management of very large datasets), variety (heterogeneous collections of structured and unstructured items), velocity (speed of generation and processing of data streams) and veracity (assessing quality, timeliness, and accuracy of data).

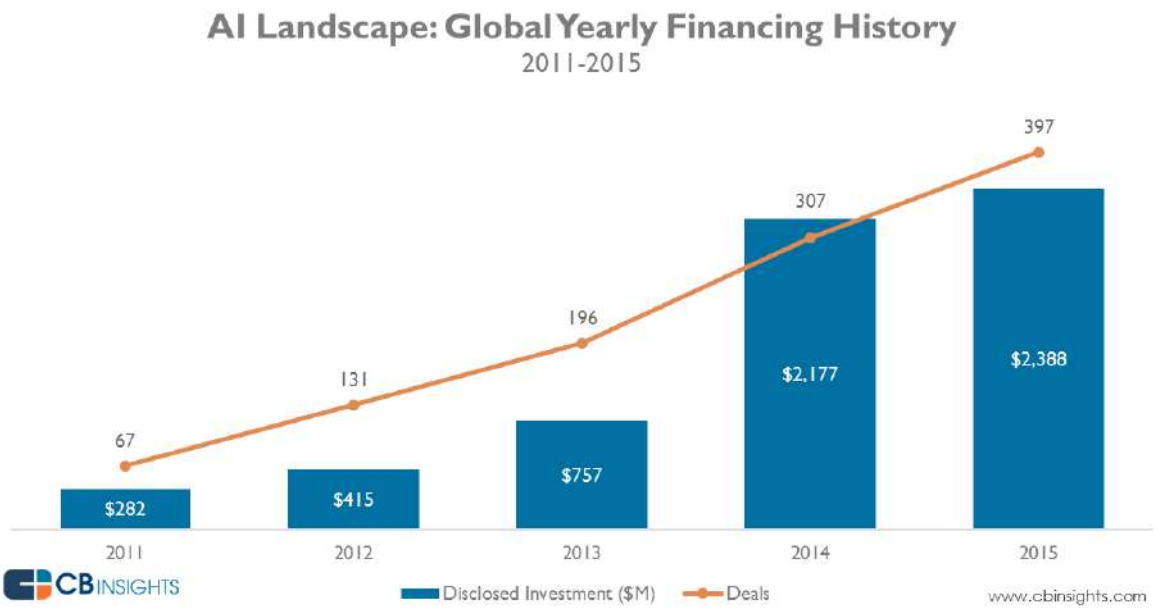
Artificial Intelligence
Artificial intelligence refers to computer systems able to exhibit behaviors, or perform tasks that normally require human intelligence. It is most frequently associated with cognitive tasks such as visual perception, speech recognition, decision-making, and translation between languages. However, more broadly, Accenture defines Artificial Intelligence as a collective term for multiple technologies that enable information systems and applications to sense, comprehend and act. That is, computers are enabled (1) to perceive the world and collect data; (2) to analyze and understand the information collected; and (3) to make informed decisions and provide guidance based on this analysis in an independent way.

Machine Intelligence
Machine intelligence extends notions of artificial intelligence and machine learning through computing techniques that allow systems to predict future actions and behaviors. As Numenta describes, rule-based models and data pattern analysis can be augmented with behavioral models that characterize normal and abnormal activities. This is essential in many situations that evolve quickly and involve many data sources such as weather prediction, modeling virus propagation, and social media analysis.

MACHINE INTELLIGENCE IS THE NEW 'GOLD RUSH'

It is therefore no surprise that Machine Intelligence is being tagged as the 'New New Thing' by entrepreneurs and investors across the globe. CBInsights reported almost 400 financial deals in AI companies in 2015, as shown in Figure 3. Investment in such start-ups more than tripled between 2013 and 2015 to reach $2.4B. As this focus expands, Deloitte has recently predicted that investment in Machine Intelligence could grow to $50B in the next five years.

Figure 3. Rapid growth in MI related start-ups



What is perhaps more significant is the interest being taken by digital leaders such as Amazon, Google and Facebook in this fast expanding area. Given the vast amount of data that each of these companies has acquired, covering every aspect our individual lifestyles, the race is now on to monetize this asset beyond pure advertising revenues. For example, Apple has acquired Seattle-based machine learning start-up, Turi, for $200 million. Google has acquired UK based Deep Minds for $500M million. Intel is intending to acquired Irish computer vision chip-maker Movidius. All these partnerships point to a deliberate focus on data mining and machine intelligence.

The maturing of this sector of information technology reinforces progress being made at the R&D level. Huge strides in computer hardware and software provide the fertile conditions for a commercial breakthrough as witnessed by the increase in start-up activity, especially in the global innovation hubs such as Silicon Valley, London, and Tel Aviv.

Big companies are also investing in their own internal projects. IBM Watson is perhaps the most visible and long standing Machine Learning programme. From first coming to public notoriety in 2011 by winning a popular US gameshow, Jeopardy, Watson has developed to the point that it is now able to store and interpret data in many different fields, from medicine and disease diagnostics to food recipes. Google is creating an open source library under its 'TensorFlow' project that could ultimately connect the entire field of human knowledge. What is especially significant here is the rapid flow of R&D discovery from academia into commercial environments – large and small.

MACHINE INTELLIGENCE OFFERS NEW ECONOMIC MODELS

In the mid twentieth century, communist dictators in populous nations such as Russia and China created highly centralized economies in which information about supply and demand was used to control the means of production from a single decision point. Such a model was proven to be ineffective due to the complexity of interpreting such vast amounts of data and has been superseded by our current free markets across the entire G20. In these free market economies, decisions relating to supply and demand are decentralized down to the individual unit of production and consumer. So far, this has vastly outperformed other economic models.

More recently, global corporations have adopted integrated ERP systems that can monitor and control complex supply chains linking production and distribution networks across 200 countries. But despite efficiency improvements, even these modern systems are proving far too rigid to adjust to rapidly changing economic and associated demand conditions produced by world events such as Brexit, Chinese debt and the US elections. Our recent survey on 'Escaping Legacy' implies that such organizations are making real efforts to dismantle such centralized systems in favor of more adaptive cloud based services.[5]

The promise of MI and associated self-learning algorithms represents a radically new and improved way of assessing and responding to shifting supply and demand patterns in a matter of seconds rather than weeks, months or years. Combining the universal availability of data on every aspect of our lives with hyper connectivity and artificial intelligence, we are in sight of powerful new algorithmic systems that could refine and re-define the entire foundation of the digital economy.

5 Surrey CoDE, "Escaping Legacy: Removing a major roadblock to a digital future", Whitepaper, 2016 available at www.SurreyCode.org

Examples of Small-Medium Enterprises (SMEs) creating MI solutions

A range of exciting new startup organizations are continually pushing the boundaries of MI, and driving requirements for data management and interconnectivity in all aspects of business delivery. Here are four illustrative examples of the diversity of MI-based research that has emerged from the University of Surrey.

BioBeats http://biobeats.com/
BioBeats is a digital health and artificial intelligence business that creates corporate and personal wellness solutions. They provide insights into an individual's health and wellbeing, by tracking data from wearable and smartphone sensors. Biometric and psychometric feedback is combined with unique machine learning algorithms, to deliver personalized stress and productivity management tools, based on clinically proven coaching techniques.

For example, BioBeats' 'Hear and Now' platform uses collected data to maximize stress reduction, engagement, and improve outcomes through the application of proprietary machine learning techniques. Quantified, continuous biometrics (Heart Rate Variability (HRV), Galvanic Skin Response (GSR)), and activity data are collected from users and are analysed by BioBeats' proprietary algorithms to evaluate and understand users' mental and physiological state.

VisualAtoms http://visualatoms.com/
VisualAtoms is developing advanced solutions in the digital vision domain. The company's expertise includes image and video analysis and coding, multimedia content description and search, computer vision, pattern recognition, ISO/IEC MPEG standardization and intellectual property generation.

Through its FIND products, VisualAtoms offers visual search engines to enable the matching of videos and pictures depicting the same objects or scenes based on visual similarities, without the need for manual annotations or metadata.

Fourth State Medicine http://fourthstatemedicine.co.uk/
Fourth State Medicine (4SM) is a medical devices company that brings a novel proprietary technology inspired from decades of research in the space sector to the forefront of medicine. The portfolio of technologies developed within 4SM have wide ranging applications across a number of medical areas and procedures. One of their first products is a plasma pen that is looking to revolutionize cosmetic and aesthetic surgery.

IKinema http://www.ikinema.com/
IKinema, a spin-out from the Surrey Space Centre, sells products that dramatically improve the quality of animation and reduce the cost of producing animation for VR, Games, Virtual Production, Engineering and Design, Live TV and many more. It uses patented IP to dynamically calculate animation sequences. The resulting animations are more realistic and cheaper to produce and maintain. The company owns patent protected intellectual property for fast, realistic and organic computation of animation.

ON THE ROAD TO DIGITAL TRANSFORMATION

Digital transformation is sweeping across all business sectors promising to change the elements of successful business models, optimize the design and delivery of new goods and services, help manage production systems more efficiently, redesigning working practices and management principles, and more. As we saw in our 2015 report 'A State of Digital Disruption' no aspect of business is immune[6]. Furthermore, the pace of change appears to be increasing. As Don Tapscott forecast[7], a generation of workers and consumers who have "grown up digital" brings a very different set of expectations, working practices, value models, etc.

The digital revolution is most visibly defined by a sea change in the way individual consumers use digital technology: it has become cheap, easy to use, consumable like a utility, always on, mobile, and open to working relatively seamlessly with technologies around it. In just a few years, whether at home and or at work, we have become sophisticated consumers and users of such technologies, and accustomed to the flexibility and freedoms they enable.

The impact on business has been equally dramatic. The initial focus was a wave of repeated efforts to upgrade to digital technologies, digital media, and digital delivery channels to open up new ways to connect with customers, clients, and stakeholders. This was the basis for realizing substantial efficiencies in areas such as customer service delivery, back office data management, and many forms of management auditing and reporting. Such savings were an essential element of business strategy during years of financial austerity following the problems in the banking industry at the start of the 21st century.

However, digital transformation has also enabled a more fundamental shift to occur. Digital transformation has opened up the opportunity for organizations to question major assumptions about the users being served, the experiences offered to them, and the most efficient ways to deliver those experiences in a coordinated, consistent and cost-effective way. Hence, digital transformation has come to mean a shifting of perspective away from the specific technologies and towards the principles on which digital-driven organizations operate. Companies lauded for their digital credentials such as Amazon or GE demonstrate a way of working that distinguishes them from their competitors. Their distinguishing features are not specific choices of technology per se, but their strategy toward business decision-making in the face of rapid change. As a number of industry observers have noted, the fuel powering the emerging digital economy is data[8].

6 Surrey CoDE, "The State of Digital Innovation: An inquiry into innovation in a digitally disrupted world", Whitepaper, 2015 available at www.SurreyCode.org.
7 Don Tapscott, "Grown Up Digital", McGraw Hill, 2009.
8 https://www.accenture.com/t20160901T103414__w__/us-en/_acnmedia/PDF-29/Accenture-Data-The-Fuel-Of-The-Digital-Economy-And-SME-Growth.pdf

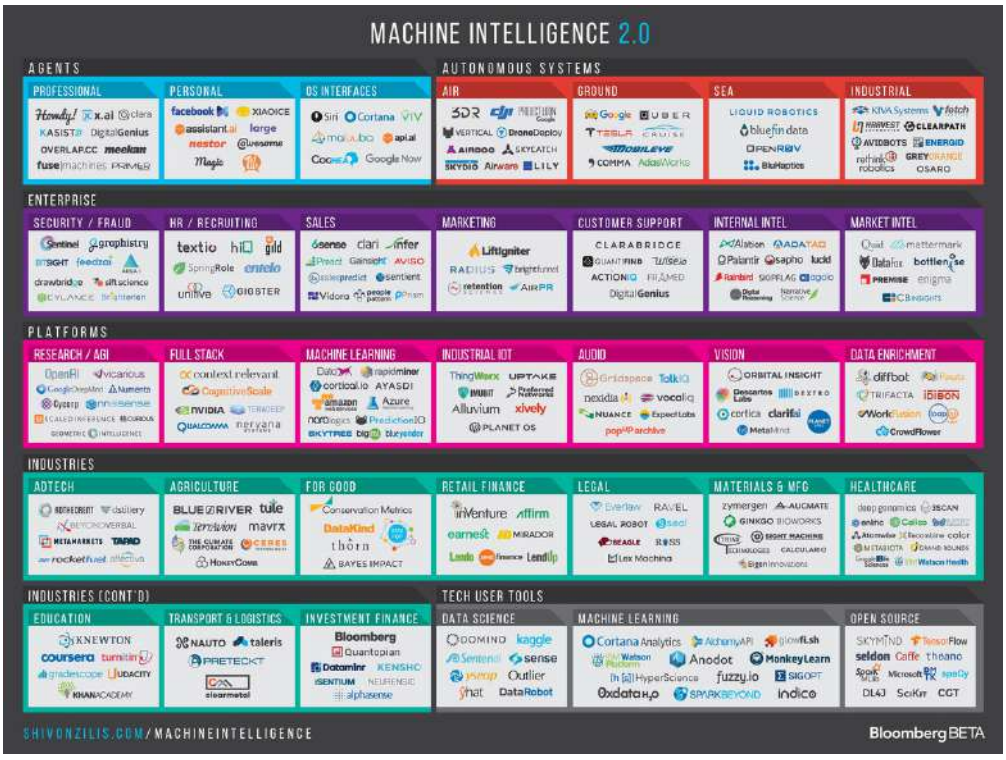
HOW WILL MACHINE INTELLIGENCE TRANSFORM WAYS OF WORKING AND INTERACTING?

Much of the current progress towards a digital economy has been focused on the automation of routine, repetitive tasks within the supply chain. Robots have been introduced into factories. Software has aided routine decisions such as inventory management and production planning. Much attention has been levelled recently on the interface with end customers through the introduction of 'omni' channels such as web access and telephone to supplement physical outlets. However, all such technologies merely reinforce the repetitive and relatively passive nature of today's supply-led economy – cheaper, faster and easier.

With the advent of MI, we see a real opportunity to begin to transform such supply networks by introducing a new paradigm based on 'sense and respond'. Through machine intelligence, commercial systems will become more adaptive to changes taking place within the external environment – at speeds that humans would have difficulty emulating. Algorithms will begin to anticipate the ever-changing needs of customers. In turn, supply networks will adapt in a continuous fashion. Ultimately, every industry will need to adopt software algorithms, driven by machine intelligence, to remain competitive and relevant.

The universal nature and impact of MI on business is illustrated in Shivon Zilis' 2016 analysis of the startup companies now offering MI capabilities. As shown in Figure 4, she categorized startups across a range of industries and technology stacks. The breadth and depth of the emerging markets, and the underlying business models they enable, is quite overwhelming, and points to an explosion of new business opportunities for both newly-created and incumbent companies.

Figure 4. The MI Startup Landscape



The capabilities that MI can deliver may be summarised as:

- From routine, manual tasks that are performed by factory robots to non-routine tasks such as self-drive cars that exploit MI to learn through experience;
- From routine, cognitive tasks such as standard business process to non-routine tasks that require professional knowledge such as medical diagnostics, and apply MI to automate complex workflows.

Such developments have enormous implications for all commercial and public organizations. We envisage MI, Big Data and Interconnectivity creating transformational change in three areas:

- **Rethinking humans** – in areas such as augmented reality, gestures and emotional recognition, with consequences for enhanced experiences and increased productivity;
- **Rethinking enterprises** – in areas such as sales, security and authentication, HR and recruitment, marketing, supply chain and more, by automating work flows;
- **Rethinking Industries** – in areas such as medicine and healthcare, legal services, manufacturing, oil and gas, and automotive by exploiting collective data and experiences.

This will have major implications for employment as many professional skills become targets for MI, in addition to repetitive manual tasks already targeted for automation. A study sponsored by Deloitte and undertaken by Oxford University estimates that up to 10M jobs are at risk in the UK alone. A dystopian view of the future of MI opens the possibility that by 2030 many of the professions will be 80-90% automated, with only a few creative tasks remaining in human hands.

WHERE WILL VALUE BE CREATED IN THE DIGITAL ECONOMY?

Rapid advances in digital technology performance, availability, and cost-effectiveness have given rise to a digital economy in which existing ways of working can be optimized primarily through increasing access and reducing the friction of many business processes though enhanced automation and increased visibility. As a result, for many public and private organizations, the significance of the digital economy is that it encourages a much broader re-assessment of business practices, with a recognition that innovation in technology frequently requires innovation in an organization's business model to recalibrate its value and guide its on-going operation.

Consequently, there has been much discussion across academia and industry of the relationship between technology innovation and business model innovation. Academics, commentators and practitioners have debated whether business model innovation can be separated from technology innovation, on the degree of influence each has on the other, where and how innovation in either of these elements impacts a firm's success, how contextual aspects such as size and maturity of both the firm and its market domain influence the rate of innovation, and much more.

Nowhere is this debate more heated than in regard to the future of MI. On-going research at the Centre for the Digital Economy(CoDE) at the University of Surrey suggests that the combination of Machine Intelligence, Big Data, and Interconnectivity will transform every element of our society:

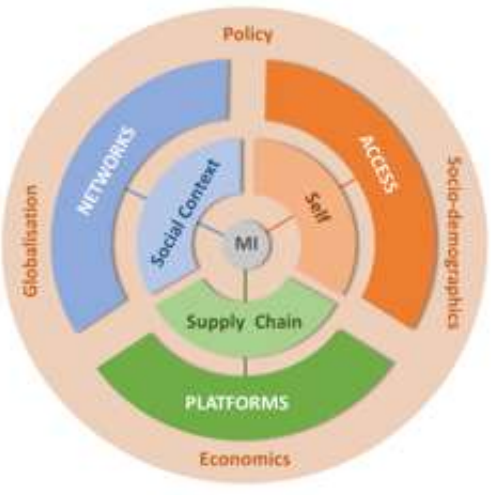
1. Connected Self – the plethora of connected devices and inputs surrounding every one of us can help predict and respond to our individual needs for high 'added value' services and enhanced experiences in areas such as physical well-being, life-long learning and financial security;

2. Increased Social Context – identifying how individuals are influenced by social networking and the impact this has on our individual needs and aspirations can generate valuable insights that lead to new products and services, as well as optimising media spend (in the hundreds of billions);

3. Connected Enterprise – interpreting the vast, real time sources of data from all elements of business interaction amongst partners, platforms and customers, through the production cycle and across distribution networks, can yield massive efficiency improvements in both physical assets and human resources.

The combination of all three areas presents opportunities for radical transformation at the policy, economic, social and technological (PEST) levels of society and commerce, as summarized in Figure 5.

Figure 5. A PEST view of Machine Intelligence



9 C. Frey and M.A. Osbourne, "The Future of Employment: How susceptible are jobs to computerization?", Whitepaper, 2013. http://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf

HOW WILL HUMAN EXPERIENCE BENEFIT FROM DIGITAL TECHNIQUES?

Through omnipresent multi-channel engagements between organizations and the stakeholders they serve, powered by the rapid growth in smart devices and wearables, organizations can collect vast amounts of data on our individual and collective behavior. Equally, they can monitor the structures that support us such as our homes, cars, and cities. Companies such as Facebook, Google and Amazon are already capturing virtually every interaction we make, and are increasingly moving to introduce MI to interpret such interactions. This could provide us with deeper insights into our personal needs and aspirations. In turn, it will enable vendors to target such needs in an ever more intimate manner.

Social media provides yet another lens on our individual and collective behavior that generates valuable intelligence in areas such as political and ethical issues, travel and entertainment, media and advertising, and so on. This can provide a context for individual decision making, as seen in examples such as Trip Adviser, where we use the experience of other travelers to help make our hotel choices, and CityMapper, where many sources of information are combined to help people select from different transportation alternatives when travelling in London.

Applying predictive analytics and MI to such information enables firms to discern distinctive patterns of behavior that can translate into new product and service offers. These can also enhance customer experience and generate new sources of value.

Examples of enhancing customer experience

- **Disney and Magic Bands** – each visitor wears a magic band that transmits data throughout the day. This enables Disney to adapt its theme parks to anticipate and overcome bottlenecks, and so improve customer experience. A $1B investment paid off in six months by extending visitor stays by up to 50%.
- **Netflix and Video Streaming** – Netflix is using Machine Intelligence to analyze viewing patterns and better match content to individual viewer habits and tastes. Equinix provides the platform for such video streaming.
- **Amazon and Book Recommendations** – Amazon is examining individual reading patterns (choice of books) as well as those of peers to improve its ability to recommend new books and other products.
- **Baidu and AskADoctor** – Chinese e-commerce giant, Baidu, has introduced a self-diagnostics service to provide low cost medical advice based on millions of individual case histories (as with IBM Watson).

10 See, for example, the discussion of Google's RankBrain activities at https://www.bloomberg.com/news/articles/2015-10-26/google-turning-its-lucrative-web-search-over-to-ai-machines

HOW COULD ENTERPRISES BE TRANSFORMED?

Manufacturers and service companies alike have long been shackled to lengthy and complex supply chains (physical and virtual) that are orchestrated by traditional ERP systems such as SAP. As widely deployed, such systems are efficient at automating repetitive and routine tasks, but do little to sense and respond to external changes. Deployments typically take years to be rolled out effectively, and are complex to update as the organization's behaviors evolve.

Such challenges are exacerbated in large manufacturing organizations where manufacturing supply chains can encompass many physical assets (machinery) as well as human driven processes and workflows. They also involve multiple hand-offs between different parties who participate in the supply chain (several thousand in the case of automotive). Hence, such manufacturing organizations need to leverage MI to ensure cost effective delivery of new processes and optimized operations. Typically, large volumes of data are generated in manufacturing plants and related operations. The application of MI across enterprise operations enhances stakeholders' ability to take decisions in real-time and formulate strategy based on evolving trends, and ensures efficient support processes. The major impacts can be seen in four key areas:

- **Manufacturing:** Operational metrics to manage day-to-day operations, and to optimize maintenance for costly equipment;
- **Finance and IT:** Better management of business and IT infrastructure investments including prediction of cash flows and currency fluctuations for managing global finance operations;
- **Workforce Analytics:** Increased visibility into workforce productivity, skills development, and team-based decision making across a diverse human capital base;
- **Sales and Marketing:** Insights into buying patterns, sales changes across different geographies, and social media comment on new promotions.

GE provides a useful illustration. GE Digital was formed in 2015 to bring new thinking to the problem of complex, multi-party supply chains. With its acquisition of Predix (an industrial cloud based platform), GE has been able to create a digital thread across the supply chain that links every component. GE has worked with Equinix to provide the interconnectivity between all such parties. By analyzing the productivity and resilience of all assets within the supply chain – human and machine – and optimizing workflows, GE is able to improve efficiencies by 20-30%, thus reducing time to market and generating higher margins.

Oil and Gas is another industry with huge potential for adoption of MI. Companies such as Tachyus offer similar machine learning capabilities in oil and gas exploration that can increase the production capacity of oil sources by 20-30%, as well as finding new sources of energy.

Most companies stand to benefit from early identification of product problems. Chat-bots are being applied to call centers to identify repetitive inquiries that represent failures in processes and products. Such Chat-bots can help managers track and eliminate root causes of failure. They can also start to displace human operators.

Such developments illustrate the trend towards connected enterprises that can exchange information and use machine intelligence to adapt to prevailing conditions. The recent maturing of Service-Orientated Architectures (SOA), and standard Application Programming Interfaces (APIs), enables new industrial models to be implemented based on principles of 'plug and play'.

ENABLING NEW BUSINESS MODELS SUCH AS 'THE SHARING ECONOMY'

Significantly, MI is challenging current thinking about where and how value is created. As we expand our ability to connect heterogeneous data sources, we now can gain insights into activities, behaviors, and trends that previously were unseen or unknowable. As a consequence, entirely new business opportunities are emerging so that businesses not only respond to current, specific requests from customers, but can also now anticipate, predict, and evolve support for their needs.

The intelligent use of data to create new business models is reflected in the recent move towards a 'sharing economy' in the shape of companies like Airbnb and Uber. Working on the basis that 'access is more valuable than ownership', these companies are able to use advanced software algorithms to develop entirely new services based on asset sharing. The speed at which such new models have gained commercial acceptance has been remarkable, and is sending shock waves through many sectors.

These businesses are able to use advanced software algorithms to respond rapidly to changes in external conditions such as traffic congestion or driver availability during peak demand (in the case of Uber). By harnessing information across complex networks in real time, such software-based organizations can demonstrate the sort of adaptability that traditional incumbents could never make. Hence, they optimize their business activities around the current customer needs, and can adjust internally to maximize efficiency of delivery of their services.

Uber and Surge Pricing

In the taxi industry, Uber has long been associated with dynamic surge pricing approaches in which various sources of real-time information are used to adjust pricing schemes in an attempt to balance supply and demand across the Uber ecosystem. While this approach may be challenged on ethical grounds, there is no doubt that the closely-guarded algorithms that it uses to analyze data and predict future patterns of use have been hugely influential in Uber's success.

In China, taxi aggregator Didi Chuxing takes the use of predictive analysis even further. Backed by Chinese internet giants Tencent and Alibaba (and a recent $1B investment from Apple), Didi currently operates in 400-plus cities and claims to control over 70 per cent of the market in mainland China. It is heavily investing in machine intelligence to develop algorithms that can predict demand by taking into account multiple variables such as income earned by a driver during that day, distance of the ride, the number of drivers in a locality, past record of individual drivers, and so on. Their use of machine intelligence is being accelerated through an open competition being managed by Udacity, with a $100k prize for the best algorithm submitted.

http://www.economist.com/news/finance-and-economics/21698656-jacking-up-prices-may-not-be-only-way-balance-supply-and-demand-taxis

http://indianexpress.com/article/technology/tech-news-technology/chinese-company-didi-chuxing-uses-artificial-intelligence-peak-hour-surge-pricing-ola-uber-2779421/

http://blog.udacity.com/2016/05/didi-and-udacity-team-up-for-100k-grand-prize-machine-learning-competition.html

NEW ARCHITECTURES FOR SUPPORTING MACHINE INTELLIGENCE

The arrival of Cloud computing is by far the most conspicuous trend in business services in recent times, and is already having a widespread impact on software delivery, making inroads in private and public sectors alike. Whether viewed as a natural extension of Internet-based computing or a completely new phenomenon, high-bandwidth interconnectivity and cheap processors and storage serve organizations by creating large computing centers that may be distributed around the globe. These centralized computing centers can be created by a single organization, shared between organizations, or be provided by third parties as a resource that can be acquired as necessary. All of these give rise to digital technology infrastructures that can be coordinated more effectively via shared service centers, and can be supported more efficiently using a flexible set of hardware and software services that can expand and contract as the organization's needs evolve.

This move towards a centralized approach for greater flexibility and efficiency in service delivery is not new. From the earliest days of computing there have been moves to centralize computer resources, share access to costly infrastructure, increase flexibility of access to common services, improve responsiveness to peak demands for capabilities, and so on. ***What is new in the recent move towards Cloud computing is the technology infrastructure that now makes that possible, the business environment that is forcing efficiencies across digital service delivery, the expanding global nature of many organizations and their supply chains, and a broader business re-evaluation of the role of digital services in support of the organization's value to its stakeholders.***

The main characteristic of a Cloud computing approach is to deliver 'convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction'. The value of this approach is that it offers a great deal of flexibility to users of those resources. In particular, capabilities can be rapidly and elastically scaled-up when demands for those capabilities increase, and similarly they can be rapidly scaled-down when demand reduces.

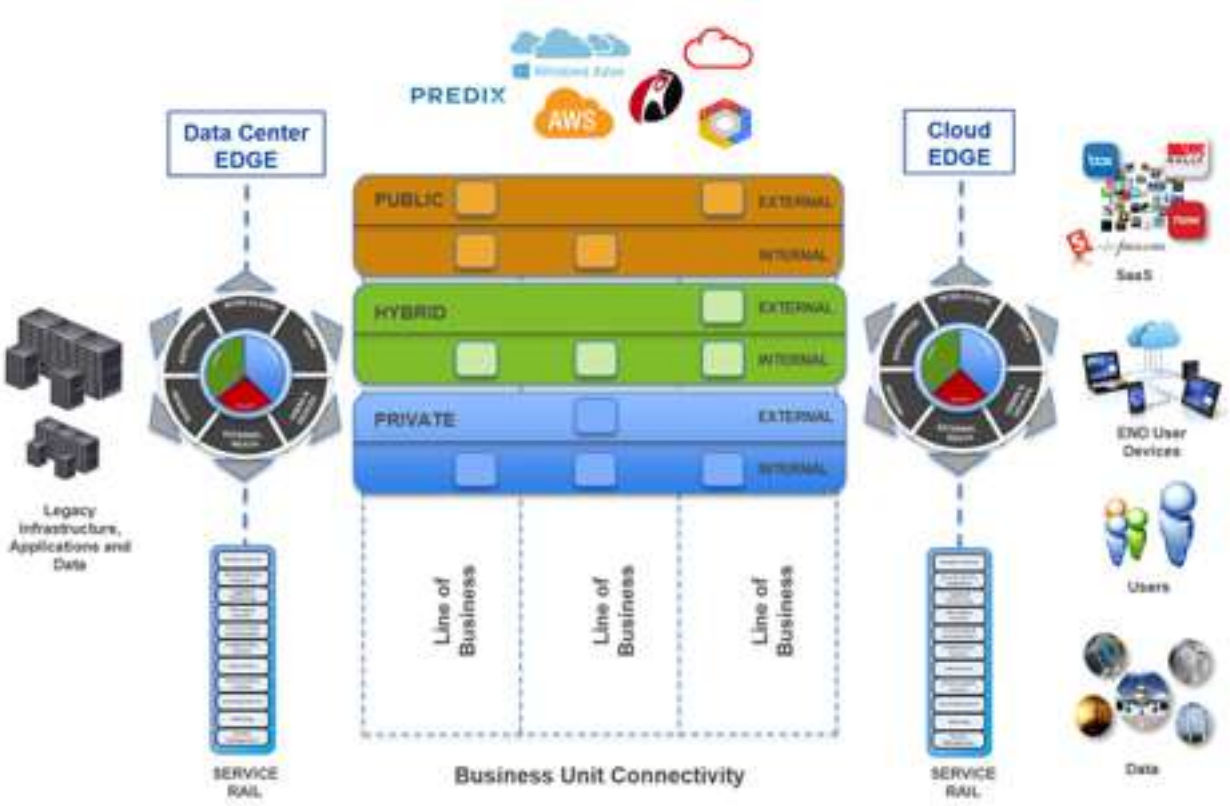
The flexibility possible with Cloud computing approaches is essential. Not only does this flexibility encourage dynamic relationships in the supply chain, it also provides much more explicit ways to look at infrastructure costs, to assign those costs to the role of each organization and team, and it encourages delivery approaches more suited to today's highly diverse and rapidly evolving organizations.

Initially, we have seen many traditional solutions ported to the Cloud platform. This is an important starting point for use of the Cloud. However, it is very limited in terms of many of the important usage scenarios for Cloud technology in more sophisticated machine intelligence applications with large heterogeneous data sets being processed at high speed using algorithms that evolve as they learn from the data.

These, and many more such scenarios, are stretching conventional processes, skills and technologies for software delivery. As illustrated in Figure 5, the architecture for managing advanced machine intelligence applications requires significant attention to complex challenges for managing these solutions. The computer power that underlies MI solutions must be supported by interconnectivity across a complex architecture of components. Architecting and running such systems is not trivial, and requires deep expertise and guidance.

11 The US National Institute of Standards and Technology (NIST) definition of cloud computing: http://csrc.nist.gov/groups/SNS/cloud-computing/cloud-def-v15.doc

Figure 5: An illustrative computer architecture



IMPLICATIONS FOR MANAGEMENT

The convergence of MI, big data and interconnectivity is happening now, and accelerating rapidly. Business needs to identify priorities and start allocating human and investment resources; the competitive advantage should not be underestimated. We recognize that there will be many challenges to overcome before the full potential of such technologies can be realized. Furthermore, different companies across a range of industries are at different places in their journey to understand and adopt MI. We advocate the following three categories of activities to exploit current technology-driven developments:

Research

- Familiarize the organization with potential applications of MI-based digital technologies and consider where high pay-off areas might reside in the organization;
- Create a clear map of the MI landscape as it affects your organization's view of the industries in which it competes, and examine new startups in your domain as early signals of market change;
- Examine new business models based on MI that could challenge the existing status quo or represent green-field opportunities.

Experiment

- Engage in open, honest discussions with your teams about the extent of data-driven decision making inside the organization, and experiment with new ways that data could be obtained, curated, and used;
- Conduct experiments or innovation sprints with appropriate partners to evaluate possibilities prior to scaling to identify Minimum Viable solutions;
- Engage in small-scale pilot deployments of MI where the focus is on learning about the processes, skills, and impact that such approaches bring to the organization.

Act

- Ensure that key roles and functional areas in your business are set up to act as appropriate entry points for MI-based innovations by engaging with start-ups and technology leaders (e.g. CTO and CIO);
- Create time in projects to build stories around success and failure that inspire and motivate teams to gain a shared understanding and vocabulary about MI and its supporting technologies;
- Promote internal successes across the organization to highlight behaviors and approaches to MI that the organization wants to replicate.

12 Steve Blank, "Why the lean startup changes everything", HBR, 2013

In the emerging digital economy where nothing is certain, the path to success is often summarized as “fast start, fast fail”. Traditional R&D approaches must be infused with an “Experiment & Scale” mindset that encourages new approaches, and rewards attempts to try alternatives. ***However, businesses cannot assume unbounded risks, and must maintain stability across key elements of their business. MI is inevitably disruptive in nature. Hence, it is essential to recognize that significant challenges may be associated with MI and its associated digital business models. These include:***

- **Changing the way data is collected and processed.** It is important to move away from localized databases associated with specific applications, and form larger data lakes that can be exploited by new layers of intelligence such as MI and Big Data;
- **Ensuring you offer a flexible, scalable technology infrastructure across your organization.** Business success requires integrating the many applications that constitute a complex set of workflows by using SOA and API techniques as well as connected platforms such as those provided by Equinix;
- **Tackling the many cultural barriers that persist in your organization.** Success in the industrial era of the twentieth century can mitigate against change in the twenty first century by encouraging business leaders to cling on to ageing business models and supporting processes. New thinking is vital.

MI-based innovations will inevitably put stress on existing organizational structures. Leadership is critical; culturechange is the goal. Companies such as Google (as a technology provider), the Spanish bank BBVA (as a business to consumer services provider), and GE Digital (as a business-to-business solutions provider) illustrate how fast progress can be made when the culture is receptive to new ideas.

YOU AIN'T SEEN NOTHING YET

As computer power continues to expand along with the ability to interconnect using high capacity mobile networks such as future 5G standards, we can expect to see MI embedded in more and more devices whether in tablets and phones, wearables, sensors in our houses, production systems at work, and so on. The promise of MI is that it will enable each of us to absorb and interpret vast amounts of data quickly and easily in order to make meaningful decisions about every aspect of our lives.

The prospect of enterprise and sector transformation is already upon us. However, there is ample opportunity to exploit the white space between sectors to create entirely new markets and radically alter existing products and services. To truly address complex individual needs, players from different sectors may need to collaborate and share data. In many such cases such as well- being, financial security and mobility, our human needs transcend today's sector boundaries. The integration of data from different sectors will provide new answers to our evolving needs. For example, in the area of personal mobility, imagine how a combination of Uber, Google Maps, Ford Automotive, EasyJet and Shell might help reduce the cost and inconvenience of modern day travel.

Ultimately, we as humans face a dilemma. MI could help us achieve full self-actualization by informing and aiding us in every aspect of our lives. However, to do this, machines will need to acquire more and more personal information to the point that they could begin to take control of our lives. Many warnings have been issued. In the book 'Homo Deus', Professor Yuval Harai paints an alarming but plausible picture in which software algorithms take control over humanity. We as individuals become mere data elements within a ubiquitous processing system. A vision for the future that is as disturbing as it is empowering.

Equally, a machine's ability to take over non-routine and cognitive tasks in a manner that could replace human input implies that the majority of today's workforce could become entirely redundant. This will place a dramatic strain on our political and social system. In harnessing MI over the coming decade, each one of us will be required to consider a wide range of factors spanning social, economic, political and ethical issues. However, far from the "beginning of the end", we need to approach MI as logical step that brings us to the "end of the beginning" of our journey toward the application of computer-based intelligence to aid humanity. Much important work remains. Addressing these issues may well be the greatest challenge for Industry 4.0, and the essence of the future of business in the digital economy.

NOTES

About CoDE

The University of Surrey's Centre for the Digital Economy (CoDE) investigates the emerging patterns of the Digital Economy through a process of Collaborative Discovery that blends research, education, problem-solving and brokering. We engage in this process with enterprises large & small, researchers and students in our Business Insights Lab. We explore topics such as digital platforms, emerging business models, cryptocurrencies and Agile innovation by combining cutting-edge business experimentation with classic methods of research. We believe that Collaborative Discovery will help us navigate – together – a world that is uncertain, unpredictable and unrecognisable to traditional business models.

Find us online at www.SurreyCoDE.org

Alan W. Brown is Professor of Entrepreneurship and Innovation at the University of Surrey's Business School. He has over 25 years of experience in commercial high tech companies leading R&D teams, building leading-edge solutions, and driving innovation in software product delivery. He is the founder and director of the Surrey 'Centre for the Digital Economy' (CoDE). His most recent co-authored book is "Digitizing Government: Understanding and implementing new digital business models"

Roger Camrass is a visiting professor at the University of Surrey and co-founder of the Surrey 'Centre for the Digital Economy'. Whilst at MIT in the seventies, Roger was a lead architect of today's Internet. Over forty years, he has helped Fortune 1000 companies harness the power of successive waves of technology. He is author of the book 'Atomic: reforming the industrial landscape into the new structures of tomorrow'.

Worldwide Corporate HQ

Equinix, Inc.
One Lagoon Drive
4th Floor
Redwood City, CA 94065
USA

Main: +1.650.598.6000
Email: info@equinix.com

EMEA

Equinix (EMEA) BV
7th Floor Rembrandt Tower
Amstelplein 1
1096 HA Amsterdam
Netherlands

Main: +31.20.753.7950
Email: info@eu.equinix.com

Asia-Pacific

Equinix Hong Kong Limited
Units 6501-04A & 6507-08, 65/F
International Commerce Centre
1 Austin Road West
Kowloon, Hong Kong

Main: +852.2970.7788
Email: info@ap.equinix.com

About Equinix

Equinix, Inc. (Nasdaq: EQIX) connects the world's leading businesses to their customers, employees and partners inside the most interconnected data centers. In 40 markets across five continents, Equinix is where companies come together to realize new opportunities and accelerate their business, IT and cloud strategies.

In a digital economy where enterprise business models are increasingly interdependent, interconnection is essential to success. Equinix operates the only global interconnection platform, sparking new opportunities that are only possible when companies come together.

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