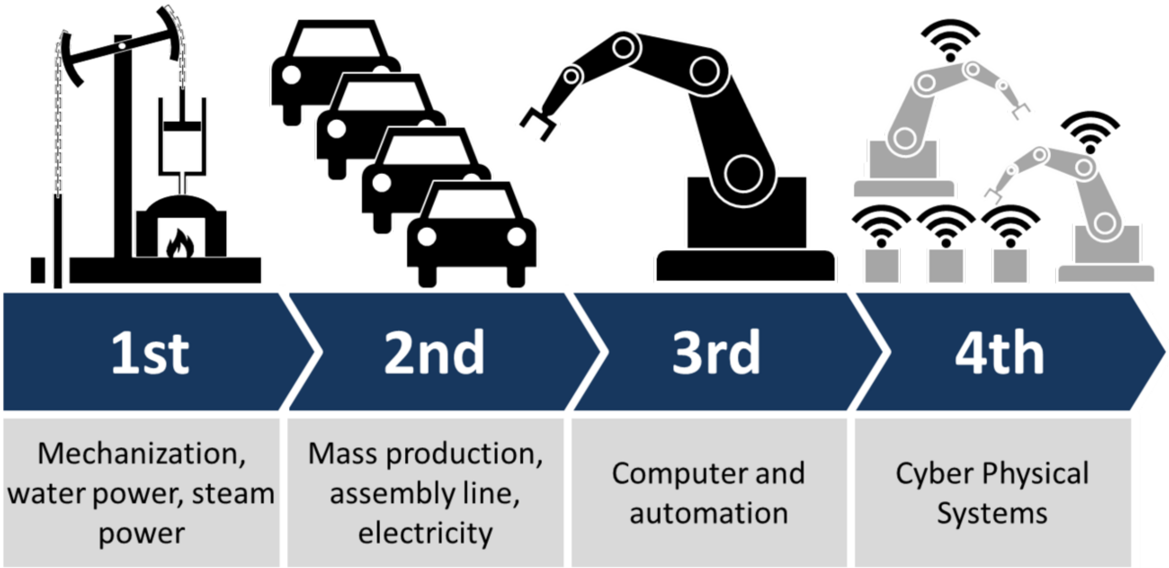
THE FOURTH INDUSTRIAL REVOLUTION

The following article on the Fourth Industrial Revolution (4IR) is a stand-alone extract taken from a much larger publication written by Dr Michael Smith in early 2020 when preparing the ground for the Aerospace Careers Programme which, as audiences to one of our schools presentations will know, has 4IR as a central theme. Naturally much has changed since 2020 because the technologies inherent in 4IR are evolving at an exponential rate which some people find, quite understandably, distressing - perhaps even frightening. However, looked at positively, to quote Klaus Schwab, the gentlemen who coined the name, 4IR can also be "a complement to the best parts of human nature – creativity, empathy, stewardship – it can lift humanity into a new collective and moral consciousness based on a shared sense of destiny." As Dr Smith, and no doubt many other people, would add, it is not technology that is evil, but the people who misuse it!

"We stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before. We do not yet know just how it will unfold, but one thing is clear, the response to it must be integrated, and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society."

Klaus Schwab, Founder & Executive Chairman, World Economic Forum, 14 January 2016.

The 18th and 19th centuries saw the first industrial revolution, especially in England to start with, and then the USA. It was a period when mostly agrarian, rural societies, became industrial and urban. The iron and textile industries, along with the development of the steam engine, played a central role. The second revolution took place from the late 19th century until just before WWI. It was a period of growth for pre-existing industries, and expansion of new ones such as steel, oil and electricity; it used electrical power to create mass production. Major technological advances during this period include the telephone, the light bulb, the phonograph and the internal combustion engine. Then came the third revolution, known today as the digital revolution, which concerned the advancement of analogue electronics and mechanical devices to digital technology. It saw the development of the personal computer, the internet, and information & communications technology. Production was automated.



The four revolutions

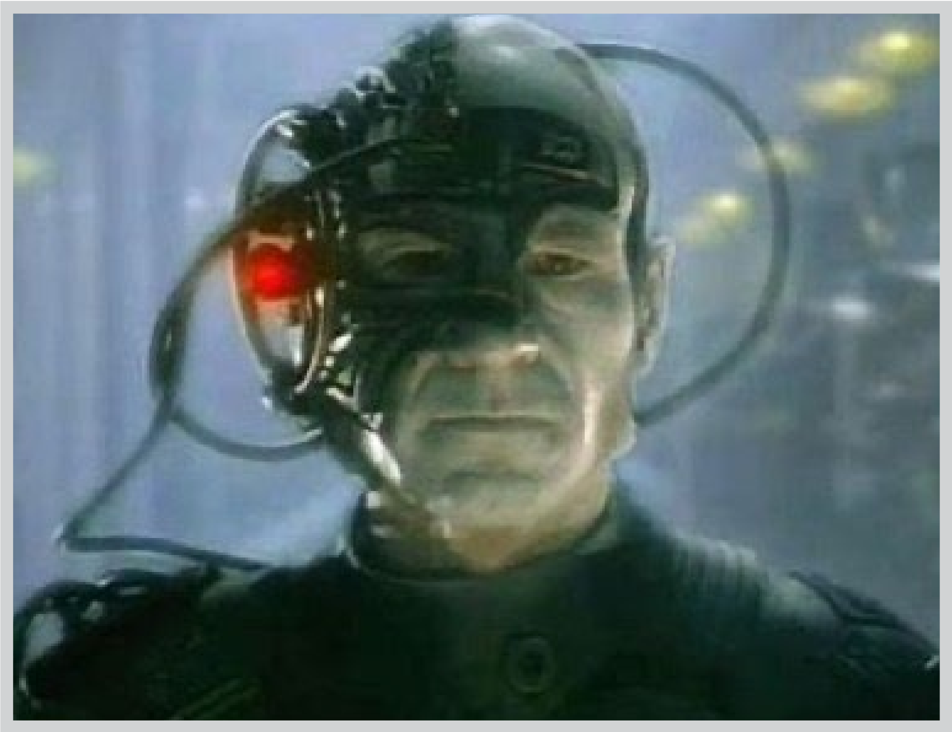
Today, four years on from Klaus Schwab's quote, we are well into the fourth industrial revolution. Whilst building on the third revolution, unlike those before it which were linear in progression, the fourth is evolving at an exponential rate. It is disrupting almost every industry in almost every country, and is characterised by a fusion of technologies that is blurring the lines between the physical, digital and biological spheres. The technology breakthroughs involved include robotics, artificial intelligence (AI) – and therefore machine learning - nanotechnology, quantum computing, biotechnology, the internet of things, additive manufacturing (3D printing), autonomous vehicles, and virtual reality, all of which are aided by what is now termed 'Big Data'.

But what does 'Big Data' mean? It used to define data sets that were so large or complex that traditional processing software was inadequate to deal with them. However, like many things that develop and evolve, their description changes. Today, the term tends to refer to the use of predictive analytics that extract value from data. Analysis of data sets can now find new correlations to identify business trends, prevent diseases, combat crime, and so on. And this is where the internet of things (IoT) comes in. Data sets grow rapidly, partly because they are increasingly gathered by inexpensive and numerous information sensing IoT equipment such as mobile devices, aerial (remote sensing) devices, software logs, cameras, microphones, radio frequency identification readers and wireless sensor networks – never mind your laptop when connected to the Internet. We now produce about 2.5 quintillion (that's 2.5 followed by 30 zeros) bytes of information every day, with over 90% of all the data in the World created in the last three years. And as the IoT evolves as everything from fitness trackers to fridges comes on-line, there's only going to be more of it. The good thing is that while the amount of data increases, so does our ability to make sense of it.

Nevertheless, the breadth and depth of the changes involved in the fourth industrial revolution herald the transformation of entire systems of production, management and governance. For the first time in humanity's existence, billions of people will be connected by mobile devices, with unprecedented processing power, storage capacity, and access to knowledge. Already AI is all around us, and growing fast in capability and usage, from self-driving cars and drones to virtual assistants, software that translates or invests, and algorithms that predict our cultural interests, all driven by exponential increases in computing power and vast amounts of data. And, in case you are wondering, the term AI is applied when a machine mimics cognitive functions that humans associate with other human minds, such as learning and problem solving. Read about Alan Turing, the father of AI who, it is estimated, shortened WWII by two years and saved 14 million lives.

In the 21st century AI techniques have become an essential part of the technology industry, helping to solve many challenging problems. The scope of AI is disputed because, as machines become increasingly capable, tasks considered as requiring 'intelligence' are often removed from the definition leading to the suggestion that "AI is whatever hasn't been done yet". Capabilities generally classified as AI in 2020 include successfully understanding human speech, strategic game systems (such as chess and go) autonomous cars, routing delivery networks, military simulations, and interpreting complex data. At present the AI field draws on computer science, mathematics, psychology, linguistics, philosophy, and neuroscience.

Furthermore, digital fabrication technologies are interacting with the biological world on a daily basis. Computational design, additive manufacturing, materials engineering, and synthetic biology are helping pioneer a symbiosis between micro-organisms, human bodies, the products we consume, and the buildings we inhabit. Indeed, we are beginning to see examples of early cyborgs (a being with both organic and biomechatronic body parts); for example, experimental artificial limbs that can be operated by electrical thought impulses from the brain. Also, the implanting of computer chips into the human body, including the brain - not that far away for Arthur C Clarke's The Final Odyssey: 3001, or the Borg from Star Trek: the Next Generation.



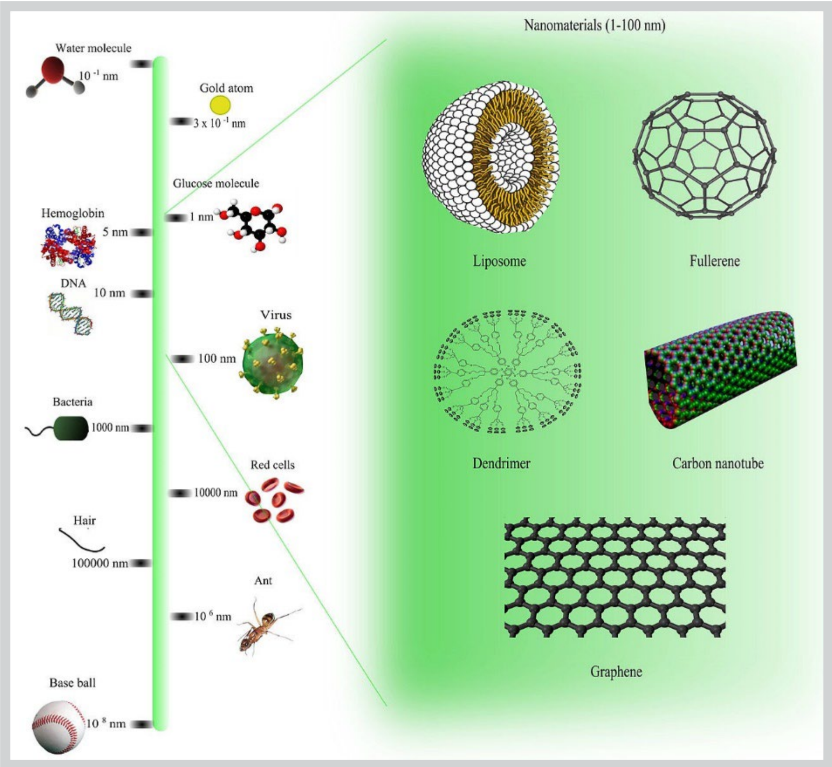
Locutus of Borg played by Patrick Stewart as Captain Picard in Star Trek: The Next Generation

And if you thought Star Trek was far-fetched, the only technologies there that have not already arrived, or are beginning to, are the transporter and warp drive (the bending of space-time to apparently travel faster than light) and even there the science involved is understood and experimentation is underway. Without wishing to utilise a pun, it is only a matter of time!

Having already considered Big Data, AI and IoT, let's have a look at some of these other technologies in a little more detail starting with Robotics, an interdisciplinary branch of engineering and science that includes mechanical engineering, electronic engineering, information engineering, computer science, and others. Robotics involves the design, construction, operation, and use of robots, as well as computer systems for their perception, control, sensory feedback, and information processing. The goal of robotics is to design intelligent machines that can help and assist humans in their day-to-day lives and keep everyone safe.

A Boston Dynamics Robot

Robotics develops machines that can substitute for humans and replicate human actions. Robots can be used in many situations and for lots of purposes, but today many are used in dangerous environments (including inspection of radioactive materials, bomb detection and deactivation), manufacturing processes, or where humans cannot survive (e.g. in space, underwater, in high heat, and clean up and containment of hazardous materials and radiation). Robots can take on any form, but some are made to resemble humans in appearance. This is said to help in the acceptance of a robot in certain replicative behaviours usually performed by people. Such robots attempt to replicate walking, lifting, speech, cognition, or any other human activity. Many of today's robots are inspired by nature, contributing to the field of bio-inspired robotics.



Nanomaterials in perspective

Turning to nanotechnology, this involves the manipulation of matter on an atomic, molecular, and supramolecular scale. The National Nanotechnology Initiative defines nanotechnology as the manipulation of matter with at least one dimension sized from 1 to 100 nanometres. This definition reflects the fact that quantum mechanical effects are important at this quantum-realm scale. Scientists currently debate the future implications of nanotechnology. On the one hand it may be able to create many new materials and devices with a vast range of applications, such as in nanomedicine, nanoelectronics, biomaterials energy production, and consumer products. On the other, nanotechnology raises many of the same issues as any new technology, including concerns about the toxicity and environmental impact of nanomaterials, and their potential effects on global economics. These concerns have led to a debate among advocacy groups and governments on whether special regulation of nanotechnology is warranted.

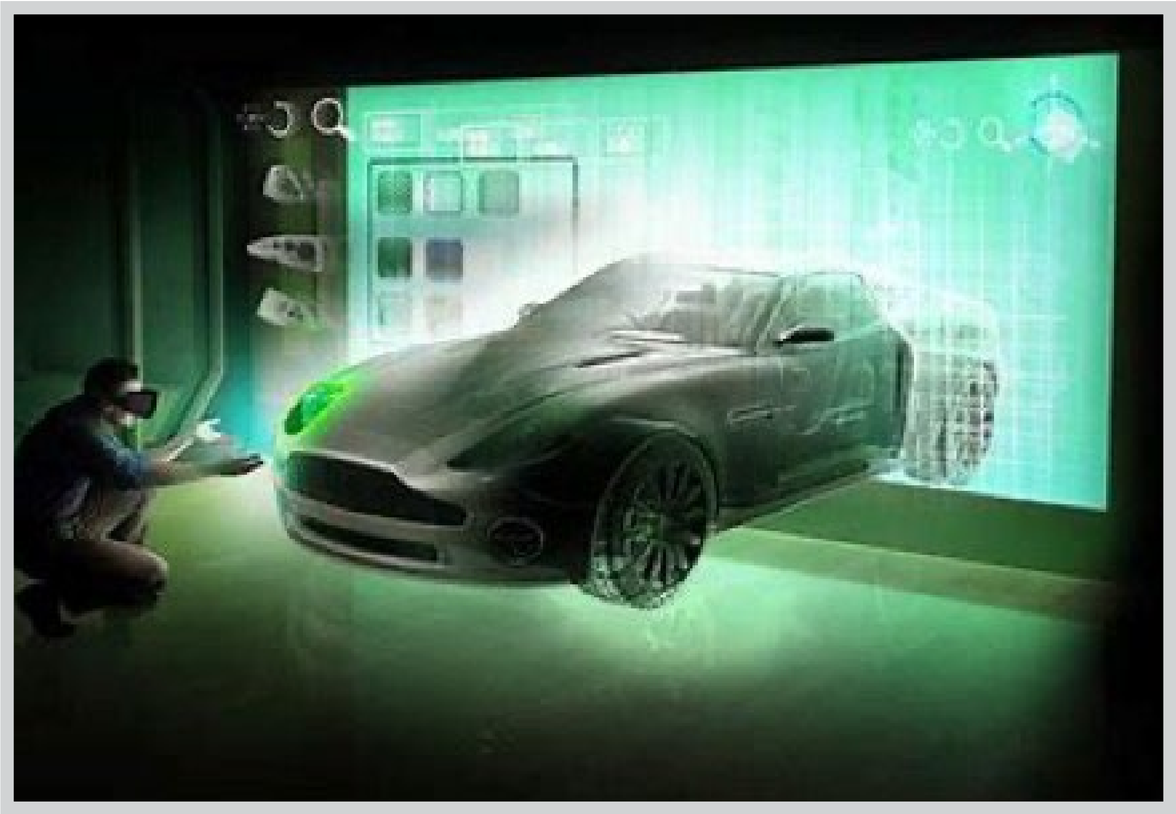
Biotechnology harnessing 4IR

Biotechnology harnesses cellular and biomolecular processes to develop new technologies and products for a range of uses, including developing new materials, more efficient industrial manufacturing processes, and cleaner, more efficient energy sources. Depending on the tools and applications, it often overlaps with the (related) fields of molecular biology, bio-engineering, biomedical engineering, biomanufacturing, and molecular engineering. In the late 20th and early 21st centuries, biotechnology has expanded to include new and diverse sciences such as genomics, recombinant gene techniques, applied immunology, and development of pharmaceutical therapies and diagnostic tests.

A small 3-D printer

3D printing builds a three-dimensional object from a computer-aided design (CAD) model, usually by successively adding material layer by layer - which is why it is also called additive manufacturing (AM) - unlike conventional machining, casting and forging processes, where material is removed from a stock item (subtractive manufacturing) or poured into a mould and shaped by means of dies, presses and hammers. AM is extremely efficient with typical wastage being 5% of material compared with up to 85% with subtractive manufacturing.

AM technologies can be broadly divided into three types. First, sintering where the material is heated, without being liquified, to create complex high-resolution objects. Direct metal laser sintering uses metal powder whereas selective laser sintering uses a laser on thermoplastic powders so that the particles stick together. Second, where the materials are fully melted by laser or electron beam. Third, stereolithography where an ultraviolet laser is fired into a vat of photopolymer resin to create torque resistant ceramic parts able to endure extreme temperatures.



A virtual Aston Martin!

Virtual reality is a simulated experience that can be similar to, or completely different from, the real world. Currently standard virtual reality systems use either virtual reality headsets or multi-projected environments to generate realistic images, sounds and other sensations that simulate a user's physical presence in a virtual environment. A person using virtual reality equipment is able to look around the artificial world, move around in it, and interact with virtual features or items (Star Trek's holodeck).

The boundaries between the real world, the virtual world, and machinery, are now breaking down. For example, we can set up a virtual version of a manufacturing facility, swap some key processes with new ideas, and run the virtual facility to see if profitability is increased. This obviously costs a great deal less than trying the same experiment in the real world, with real manufacturing facilities.

One example of a quantum computer

Underpinning it all are new computational technologies enabling ever more powerful computers to process increasingly larger amounts of data. In particular, the quantum computer above. But what is a quantum computer and why is it different from the one you have on your desk or in your hand? Quantum computing is based on quantum bits or qubits which, themselves, are based on quantum theory that was born at the beginning of the 20th century out of the work of Max Planck and the later work of Werner Heisenberg (who developed the 'uncertainty principle') and the now famous 'Schrödinger's cat', which heralded the digital revolution of yesterday and has led to the fourth industrial revolution of today.

Schrödinger's cat is a thought experiment, sometimes described as a paradox, devised by Austrian physicist Erwin Schrödinger in 1935, though the idea originated from Albert Einstein. It illustrates what he saw as the problem of the Copenhagen interpretation of quantum mechanics applied to everyday objects. The scenario presents a hypothetical cat that may be simultaneously both alive and dead, a state known as a quantum superposition, as a result of being linked to a random subatomic event that may or may not occur.

Unlike traditional computers in which bits must have a value of either zero or one, a qubit can represent a zero, a one, or both values at the same time. As such, quantum computers may be able to solve certain problems in a few days that would take millions of years for a classical computer. And because we are dealing with the esoteric world of quantum physics - thinking out of the box. In October 2019 Google announced they had created a device known as 'Sycamore' which they claimed had taken just over three minutes to complete a calculation that would have taken IBM's Summit supercomputer 10,000 years. Not surprisingly IBM are contesting.

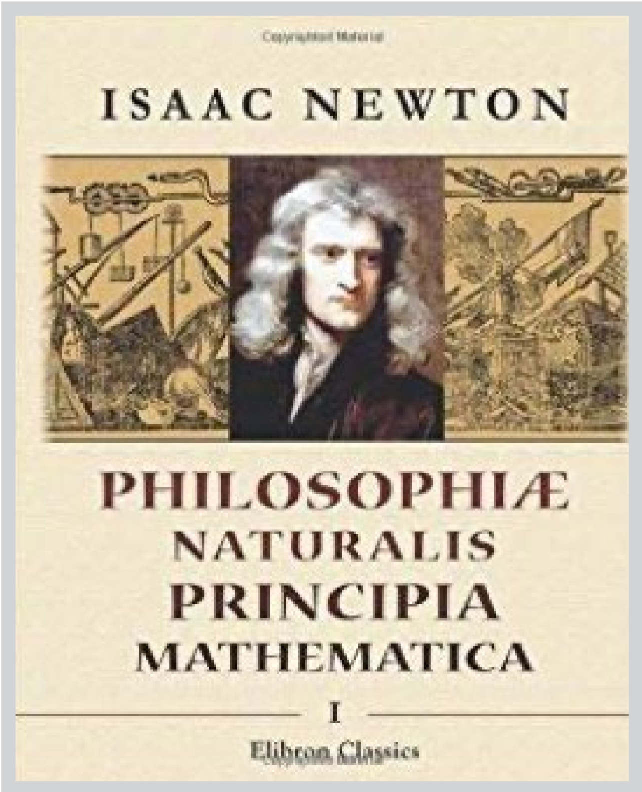
The fourth industrial revolution encompasses areas not normally classified as an industry, such as smart cities which have been described as an urban area that uses different types of electronic IoT sensors to collect data and then use insights gained from that data to manage assets, resources and services efficiently. This includes data collected from citizens, devices, and assets that is processed and analysed to monitor and manage traffic and transportation systems, power plants, utilities, water supply networks, waste management, crime detection, information systems, schools, libraries, hospitals, and other community services. In the UK, Bristol and London are leading this development.

Within Industry itself the fourth industrial revolution has created what has become known as Industry 4.0 which is the trend towards automation and data exchange in manufacturing technologies and processing involving cyber-physical systems, IoT, the Industrial Internet of Things (IIOT), cloud computing, cognitive computing and artificial intelligence. This trend is leading to "smart factories" where, within a modular structure, cyber-physical systems (which include Big Data and AI) monitor physical processes, create a virtual copy of the physical world (remember digital twins) and make decentralized decisions. Over the IoT, cyber-physical systems (CPS) communicate and cooperate with each other and with humans in real time, and via the Internet, both internal and cross-organizational services, are offered and used by participants of the value chain.

But what is a CPS? It is a mechanism that is controlled or monitored by computer-based algorithms, tightly integrated with the Internet and its users (hence the term IoT for example). In cyber-physical systems, physical and software components are deeply intertwined, each operating on different spatial and temporal scales, exhibiting multiple and distinct behavioral modalities, and interacting with each other in ways that change with context. Examples of CPS include a smart electrical grid, autonomous automobile systems, medical monitoring, process control systems, robotics systems, and automatic pilot avionics. Consequently, in a smart factory decision making is undertaken in a split second under the management of a central computer. This is coming into existence today and is part of what the aerospace industry is now referring to as 'Aerospace 4.0'.

A 'Smart Factory'

The determining factor in all of this is the pace of change. The coordination of the speed of technical development and, as a result, socio-economic and infrastructural transformations, with human life allows us to take a qualitative leap in the speed of development which, according to the *Scientific and Technical Journal of St. Petersburg State Polytechnical University* marks a transition to a new time era.



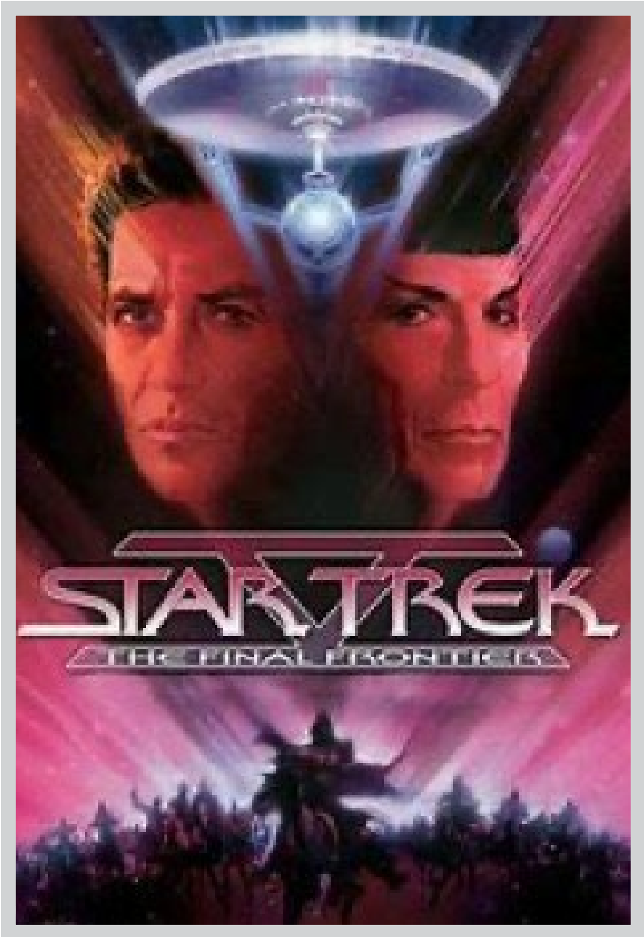
Colfe's School, Michael Smith's Alma Mater and the ACP's educational partner, was established (1652) at a time when the European world was about to embark on a period of immense change, sometimes referred to as the 'Age of Enlightenment' (1685 – 1815). And not surprisingly a very significant element of that period was what has become known as the 'Scientific Revolution' which concluded in 1687 with the publication of Isaac Newton's grand synthesis, *Philosophiæ Naturalis Principia Mathematica*, one of the most important works in the history of science. The Enlightenment period affected all aspects of society, the initiating catalyst for which was the preceding scientific revolution, just as the fourth industrial revolution is impacting the world today.

Let us consider that change for a few minutes. In 1652 most people believed that the Earth was the centre of the Universe, with the Sun, the Moon and the then known planets circling around it, and the stars being holes in the Biblical Firmament. The Great Plague was seen as a visitation by God on the sins of the people, and 25% of children died before reaching 5 years of age, and 40% before reaching adulthood. Today, children are being born who will routinely live to be 100; and the integration of machines and humans into 'quasi-cyborgs' and the development of designer babies through genetic engineering could easily extend that life-span for those who could afford the cost. Some of our children today will walk on the face of planet Mars; in 1652 most people did not even leave their villages or towns. And even Isaac Newton was a fervent alchemist searching for the Philosopher's Stone to turn base metal into gold!

Alchemy, the medieval forerunner of chemistry concerned with the transmutation of matter or finding a universal elixir.

It is a fact that technological advancement is now both exponential and accelerating. As stated before, this is the big difference between the fourth industrial revolution and those that preceded it. Every 12 to 18 months computers double their capabilities, and so do the information technologies that use them. And this 'Law of Accelerating Returns' is getting faster and faster. For example, it is calculated that in five years' time technology will be 32 times more advanced than it is today; in 10 years, one thousand times; in 20 years, one million times; in 30 years, one billion times; in 40 years, one trillion times; and in 50 years, one quadrillion. It has been suggested that before the end of the 21st century there will have been an explosion of highly intelligent biological, non-biological, micro, nano, virtual, mixed, and morphing life forms colonizing our solar system.

If you are sceptical, do not be so. At the end of the 19th century most scientists proclaimed that humankind had learnt everything there was to know about the world around us, and then a little-known German born patent clerk in Switzerland came along - Albert Einstein - and a whole new world opened up. Since then such advancement in knowledge (albeit not necessarily understanding, because no one is yet quite certain how quantum physics really works, they just know that is does; hence the iPhone in your hand) has kept happening, and with the advent of the technologies of today (and those being developed for tomorrow) now driving such exponential growth, the stars really are Gene Roddenberry's "Final frontier".



You will recall the significance of AI within the fourth industrial revolution. John McNamara, of the IBM Hursley Innovation Centre, has submitted evidence to the House of Lords Artificial Intelligence Committee - when considering the economic, ethical and social implications of AI - that within just two decades, technology may have advanced so much that humans and machines are effectively 'melded' together, allowing for huge leaps forward in human consciousness and cognition. *"We may see AI nano-machines being injected into our bodies,"* he told peers. *"These will provide huge medical benefits, such as the ability to repair damaged cells, muscles and bones - perhaps even augmenting them."* Furthermore, scientists at companies (for example Microsoft) are already developing a computer made from DNA which could live inside cells and look for faults in bodily networks, such as cancer, and eliminate them by 're-booting' the cell.

He went on to say that *"Beyond this, utilising technology which is already being explored today, we see the creation of technology that can meld the biological with the technological, and so enhance human cognitive capability directly, and the ability to utilise vast quantities of computing power so augmenting our thought processes. Using this technology, embedded in ourselves and in our surroundings, we will begin to be able to control our environment with thought and gestures alone."*

However, he also warned that the rise of AI could bring widespread unemployment. *"Whereas today, being poor means being unable to afford the latest smart phone, tomorrow this could mean the difference between one group of people potentially having an extraordinary uplift in physical ability, cognitive ability, health and life span, and another much wider group that do not."*

Moreover, Noel Sharkey, Emeritus Professor of AI and Robotics, University of Sheffield, who is now Director of the Foundation for Responsible Robotics, has stated: *"The immediate concern is that by ceding decisions or control to machines, the humans start accepting the machines' decisions as correct, or better than their own, and stop paying attention. Furthermore, there is a growing body of evidence that the learning machine decision-makers are inheriting many invisible biases among their correlations."* So, whilst bringing great advantages, AI may also be accompanied by disruption, potential discrimination, substantial risk, and significant job displacement, as well as creation.

The truth is that, as predicted by the 'The Future of Humanity Institute' at the University of Oxford, *"AI is likely to exceed human performance in most cognitive domains."* As an example of this, you are invited to read about the latest super computer self-learning programme (AlphaGo Zero, named after the Chinese board game 'Go', the most complex and demanding strategy game ever devised) created by DeepMind Technologies that has not only absorbed all human knowledge to date in just 40 days, but has now demonstrated, in the words of Demis Hassabis, CEO of DeepMind, *"genuine moments of creativity"* having defeated the 'Go' world champion in the first two games of a three-game series.

Mr Hassabis advises that AlphaGo Zero is already studying protein mis-folding, one of the causes of such diseases as Alzheimer's and Parkinson's, and goes on to say that it is so powerful because it is *"no longer constrained by the limits of human knowledge"*. Such a capability has the potential for enormous beneficial impact when applied to all sorts of apparently intractable problems. On the other hand, one can reasonably ask, is there also here just a touch of George Orwell's dystopian *Nineteen Eighty Four*?

IN CONCLUSION

Having started this section with a quote from Klaus Schwab, we conclude with an extract from his article entitled *'The Fourth Industrial Revolution: what it means, how to respond'* published by the World Economic Forum in 2016.

"Like the revolutions that preceded it, the Fourth Industrial Revolution has the potential to raise global income levels and improve the quality of life for populations around the world. To date, those who have gained the most from it have been consumers able to afford and access the digital world; technology has made possible new products and services that increase the efficiency and pleasure of our personal lives. Ordering a cab, booking a flight, buying a product, making a payment, listening to music, watching a film, or playing a game—any of these can now be done remotely.

In the future, technological innovation will also lead to a supply-side miracle, with long-term gains in efficiency and productivity. Transportation and communication costs will drop, logistics and global supply chains will become more effective, and the cost of trade will diminish, all of which will open new markets and drive economic growth.

At the same time, as the economists Erik Brynjolfsson and Andrew McAfee have pointed out, the revolution could yield greater inequality, particularly in its potential to disrupt labour markets. As automation substitutes for labour across the entire economy, the net displacement of workers by machines might exacerbate the gap between returns to capital and returns to labour. On the other hand, it is also possible that the displacement of workers by technology will, in aggregate, result in a net increase in safe and rewarding jobs.

We cannot foresee at this point which scenario is likely to emerge, and history suggests that the outcome is likely to be some combination of the two. However, I am convinced of one thing—that in the future, talent, more than capital, will represent the critical factor of production. This will give rise to a job market increasingly segregated into "low-skill/low-pay" and "high-skill/high-pay" segments, which in turn will lead to an increase in social tensions.

In addition to being a key economic concern, inequality represents the greatest societal concern associated with the Fourth Industrial Revolution. The largest beneficiaries of innovation tend to be the providers of intellectual and physical capital—the innovators, shareholders, and investors—which explains the rising *gap in wealth between those dependent on capital versus labour. Technology is therefore one of the main reasons why incomes have stagnated, or even decreased, for a majority of the population in high-income countries: the demand for highly skilled workers has increased while the demand for workers with less education and lower skills has decreased. The result is a job market with a strong demand at the high and low ends, but a hollowing out of the middle.*

This helps explain why so many workers are disillusioned and fearful that their own real incomes and those of their children will continue to stagnate. It also helps explain why middle classes around the world are increasingly experiencing a pervasive sense of dissatisfaction and unfairness. A winner-takes-all economy that offers only limited access to the middle class is a recipe for democratic malaise and dereliction.

Discontent can also be fuelled by the pervasiveness of digital technologies and the dynamics of information sharing typified by social media. More than 30 percent of the global population now uses social media platforms to connect, learn, and share information. In an ideal world, these interactions would provide an opportunity for cross-cultural understanding and cohesion. However, they can also create and propagate unrealistic expectations as to what constitutes success for an individual or a group, as well as offer opportunities for extreme ideas and ideologies to spread.

The impact on business

An underlying theme in my conversations with global CEOs and senior business executives is that the acceleration of innovation and the velocity of disruption are hard to comprehend or anticipate and that these drivers constitute a source of constant surprise, even for the best connected and most well informed. Indeed, across all industries, there is clear evidence that the technologies that underpin the Fourth Industrial Revolution are having a major impact on businesses.

On the supply side, many industries are seeing the introduction of new technologies that create entirely new ways of serving existing needs and significantly disrupt existing industry value chains. Disruption is also flowing from agile, innovative competitors who, thanks to access to global digital platforms for research, development, marketing, sales, and distribution, can oust well-established incumbents faster than ever by improving the quality, speed, or price at which value is delivered.

Major shifts on the demand side are also occurring, as growing transparency, consumer engagement, and new patterns of consumer behaviour (increasingly built upon access to mobile networks and data) force companies to adapt the way they design, market, and deliver products and services.

A key trend is the development of technology-enabled platforms that combine both demand and supply to disrupt existing industry structures, such as those we see within the "sharing" or "on demand" economy. These technology platforms, rendered easy to use by the smartphone, convene people, assets, and data— thus creating entirely new ways of consuming goods and services in the process. In addition, they lower the barriers for businesses and individuals to create wealth, altering the personal and professional environments of workers. These new platform businesses are rapidly multiplying into many new services, ranging from laundry to shopping, from chores to parking, from massages to travel.

On the whole, there are four main effects that the Fourth Industrial Revolution has on business—on customer expectations, on product enhancement, on collaborative innovation, and on organizational forms. Whether consumers or businesses, customers are increasingly at the epicentre of the economy, which is all about improving how customers are served. Physical products and services, moreover, can now be enhanced with digital capabilities that increase their value. New technologies make assets more durable and resilient, while data and analytics are transforming how they are maintained. A world of customer experiences, data-based services, and asset performance through analytics, meanwhile, requires new forms of collaboration, particularly given the speed at which innovation and disruption are taking place. And the emergence of global platforms and other new business models, finally means that talent, culture, and organizational forms will have to be rethought.

Overall, the inexorable shift from simple digitization (the Third Industrial Revolution) to innovation based on combinations of technologies (the Fourth Industrial Revolution) is forcing companies to re-examine the way they do business. The bottom line, however, is the same: business leaders and senior executives need to understand their changing environment, challenge the assumptions of their operating teams, and relentlessly and continuously innovate.

The impact on government

As the physical, digital, and biological worlds continue to converge, new technologies and platforms will increasingly enable citizens to engage with governments, voice their opinions, coordinate their efforts, and even circumvent the supervision of public authorities. Simultaneously, governments will gain new technological powers to increase their control over populations, based on pervasive surveillance systems and the ability to control digital infrastructure. On the whole, however, governments will increasingly face pressure to change their current approach to public engagement and policymaking, as their central role of conducting policy diminishes owing to new sources of competition and the redistribution and decentralization of power that new technologies make possible.

Ultimately, the ability of government systems and public authorities to adapt will determine their survival. If they prove capable of embracing a world of disruptive change, subjecting their structures to the levels of transparency and efficiency that will enable them to maintain their competitive edge, they will endure. If they cannot evolve, they will face increasing trouble.

This will be particularly true in the realm of regulation. Current systems of public policy and decision-making evolved alongside the Second Industrial Revolution, when decision-makers had time to study a specific issue and develop the necessary response or appropriate regulatory framework. The whole process was designed to be linear and mechanistic, following a strict "top down" approach.

But such an approach is no longer feasible. Given the Fourth Industrial Revolution's rapid pace of change and broad impacts, legislators and regulators are being challenged to an unprecedented degree and for the most part are proving unable to cope.

How, then, can they preserve the interest of the consumers and the public at large while continuing to support innovation and technological development? By embracing "agile" governance, just as the private sector has increasingly adopted agile responses to software development and business operations more generally. This means regulators must continuously adapt to a new, fast-changing environment, reinventing themselves so they can truly understand what it is they are regulating. To do so, governments and regulatory agencies will need to collaborate closely with business and civil society.

The Fourth Industrial Revolution will also profoundly impact the nature of national and international security, affecting both the probability and the nature of conflict. The history of warfare and international security is the history of technological innovation, and today is no exception. Modern conflicts involving states are increasingly "hybrid" in nature, combining traditional battlefield techniques with elements previously associated with non-state actors. The distinction between war and peace, combatant and non-combatant, and even violence and non-violence (think cyberwarfare) is becoming uncomfortably blurry.

As this process takes place and new technologies such as autonomous or biological weapons become easier to use, individuals and small groups will increasingly join states in being capable of causing mass harm. This new vulnerability will lead to new fears. But at the same time, advances in technology will create the potential to reduce the scale or impact of violence, through the development of new modes of protection, for example, or greater precision in targeting.

The impact on people

The Fourth Industrial Revolution, finally, will change not only what we do but also who we are. It will affect our identity and all the issues associated with it: our sense of privacy, our notions of ownership, our consumption patterns, the time we devote to work and leisure, and how we develop our careers, cultivate our skills, meet people, and nurture relationships. It is already changing our health and leading to a "quantified" self, and sooner than we think it may lead to human augmentation. The list is endless because it is bound only by our imagination.

I am a great enthusiast and early adopter of technology, but sometimes I wonder whether the inexorable integration of technology in our lives could diminish some of our quintessential human capacities, such as compassion and cooperation. Our relationship with our smartphones is a case in point. Constant connection may deprive us of one of life's most important assets: the time to pause, reflect, and engage in meaningful conversation.

One of the greatest individual challenges posed by new information technologies is privacy. We instinctively understand why it is so essential, yet the tracking and sharing of information about us is a crucial part of the new connectivity. Debates about fundamental issues such as the impact on our inner lives of the loss of control over our data will only intensify in the years ahead. Similarly, the revolutions occurring in biotechnology and AI, which are redefining what it means to be human by pushing back the current thresholds of life span, health, cognition, and capabilities, will compel us to redefine our moral and ethical boundaries.

Shaping the future

Neither technology nor the disruption that comes with it is an exogenous force over which humans have no control. All of us are responsible for guiding its evolution, in the decisions we make on a daily basis as citizens, consumers, and investors. We should thus grasp the opportunity and power we have to shape the Fourth Industrial Revolution and direct it toward a future that reflects our common objectives and values. To do this, however, we must develop a comprehensive and globally shared view of how technology is affecting our lives and reshaping our economic, social, cultural, and human environments. There has never been a time of greater promise, or one of greater potential peril. Today's decision-makers, however, are too often trapped in traditional, linear thinking, or too absorbed by the multiple crises demanding their attention, to think strategically about the forces of disruption and innovation shaping our future.

In the end, it all comes down to people and values. We need to shape a future that works for all of us by putting people first and empowering them. In its most pessimistic, dehumanized form, the Fourth Industrial Revolution may indeed have the potential to "robotize" humanity and thus to deprive us of our heart and soul. But as a complement to the best parts of human nature—creativity, empathy, stewardship—it can also lift humanity into a new collective and moral consciousness based on a shared sense of destiny. It is incumbent on us all to make sure the latter prevails."