AUTOMATION AND AUTONOMY.

Institution of MECHANICAL ENGINEERS

Improving the world through engineering

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Government needs to increase its emphasis on research & development, skills and lifelong learning, if the UK is to be at the forefront of the artificial intelligence and data revolution.

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This case study has been produced in the context of the Institution's strategic themes of education, energy, environment, healthcare, manufacturing, transport and its vision of 'Improving the world through engineering'.

Cover image
Versius Surgical Robotic System. Designed to meet the complex requirements of laparoscopic surgery while its bio-mimicking form allows surgeons to work in a way that reduces physical and mental effort.

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Automation and Autonomy

Society has long been comfortable with, indeed fascinated by, automation. From the Ancient Greeks working to measure time accurately, to Georgian automaton toys, machines have been created to perform repeated identical tasks accurately. These actions can look quite complex, as in writing a letter in neat handwriting, but there is no thought process or artificial intelligence (AI) in these devices. If it wasn't programmed in beforehand, then it just won't happen. A more modern example is the robotic lawnmower. These often have an ability to measure when they need recharging, and a knowledge of where the recharging point is so that they can reach it automatically. They can also back away from unexpected objects. In the end however, they cannot 'see' the outcome of their work. They don't share the same ambition for a neatly cut lawn. They are just doing what has been pre-programmed during their manufacture.

The reality is, however, that as computing power continues to increase, the pre-programming can become ever more complex. This extends the region of application of automation away from simple mechanical processes, into more complex process control or human interaction. The question is therefore whether we are really ready for that.

Image: Maillardet's Automation (c 1800)[1]

A survey released by the EPSRC[2] for National Robotics Week 2018 showed that just 20% of UK adults felt that we were 'living in harmony' with robotics technology and autonomous machines. Slightly more felt that there should be ethical laws around what work robots could do, and strangely 13% thought there should be an upper limit on the number of hours robots can work per day.

As with all technologies however, 'the genie is out of the bottle'. Automation will increasingly turn into autonomy. Ever-more powerful computers will be able to 'learn' and modify the behaviour of the systems they are controlling. Rather than just replacing humans with repetitive tasks, they will be able to iterate themselves towards achieving a desired outcome. Examples shown in this report are taken from the three case studies from manufacturing, industrial process control and human healthcare. The issues raised relate not just to which current jobs will disappear and which will be created, but to the ability of our economy and our education system to keep up. In the past it has been shown that there is a need for those slightly ahead in the technology race, to reach back and help those coming along after them to ensure a successful future.

The Institution of Mechanical Engineers recommends that:

- The current UK Government Industrial Strategy increases its emphasis on research & development, skills and lifelong learning, as part of its Grand Challenge to put the UK at the forefront of artificial intelligence and the data and automation revolution.
- Innovate UK investments in digital technology, especially the Digital Catapult, the High Value Manufacturing Catapult and the Knowledge Transfer Network 4Manufacturing, are incentivised to work with schools, colleges and universities to strengthen the links between the needs of the digital economy, and current teaching and learning.
- A campaign of public engagement, building on Year of Engineering 2018, is created to increase public understanding, and also influence Government and industry policy regarding the future development and adoption of automation and autonomy for societal benefit.

When Does Automation Become Autonomy?

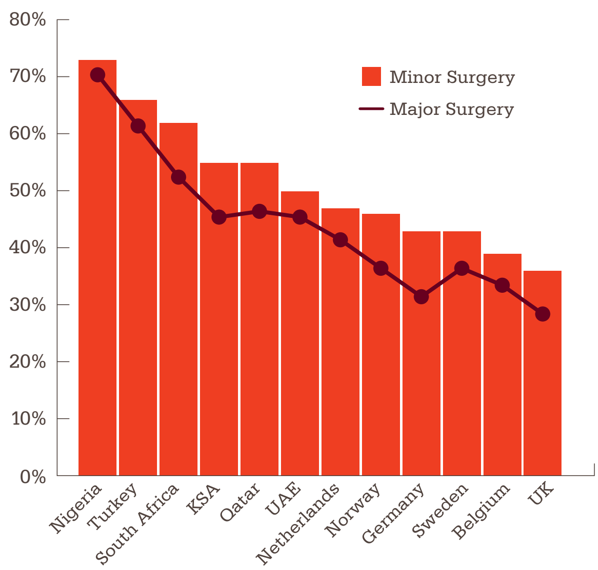
A previous case study by IMechE looked at the recent developments in driverless cars. It structured developments against the increasingly accepted SAE model[3] which describes the transition from individual automatic processes at one end to full independence of behaviour at the other.

What is immediately clear is that while society is already very comfortable with activity at the lowest level (eg shorter braking distances in emergencies from an automatic braking system), it is still sceptical about the costs and safety implications of operating at level 5. This is despite the fact that car accidents (with no autonomy as yet) are still a major cause of premature loss of life in the UK (1,710 deaths between June 2016 and June 2017). A similar nervousness was found in a recent survey on level 5 robotic surgery.[4]

Table 1: Recent autonomous developments in driverless cars

Autonomy Level	Developments
1. Driver Control	– Cruise control – ABS – ESC
2. Assisted Driving	– AEB – Adaptive cruise control – Parking and lane keep assistance
3. Partial Autonomy	– Adaptive cruise control with lane keeping – Traffic jam assistance
4. High Autonomy	– Road following – Juction decisioning – Hazard detection and evasive decisioning
5. Full Autonomy	– Combination of all functions and artificial intelligence and multiple redundancies – no driver monitoring

Figure 1: Willingness to have surgery performed by robots[4]



It is interesting to note the cultural impact on acceptability, with some countries clearly more open to doing what by others is seen as taking unnecessary risk. They key issue is perhaps that when something is already seen to be risky, the use of technology which might add further complication is not naturally seen to be of benefit.

And yet, the ability of computers to outperform humans is well known. That is not simply in terms of arithmetical speed, but also in evaluation of options. Memorably, the world chess champion at the time, Garry Kasparov, was willing to compete with a computer, Deep Blue, and while he won in 1996, a year later he was narrowly beaten. Since then computing power has continued to increase, much in line with the original Moore's Law of doubling every 18 months. It means that with already in excess of 2 billion smartphones in the world, the majority of the adult population have remarkable computing power at their personal disposal. The comparison with the guidance computer on the Apollo moon mission shows just how far technology has developed in the last 50 years.[5]

Apollo Guidance Computer (AGC)

Dimensions:	24 x 12.5 x 6.5 inches
Weight:	70 pounds
Processor speed:	1 MHz
Memory:	2,048 words (32,768 bits or roughy 4kB)
Display:	Seven segment numeric
Price:	$150,000 (est.)

Apple iPhone 5s

Dimensions:	4.87 x 3.31 inches
Weight:	3.95 ounces
Processor speed:	1.3GHz Dual Core
Memory:	64GB
Display:	4-inch diagonal multi-touch display 1136 x 640 pixel resolution at 326ppi
Price:	$399

Robots Are Taking Our Jobs

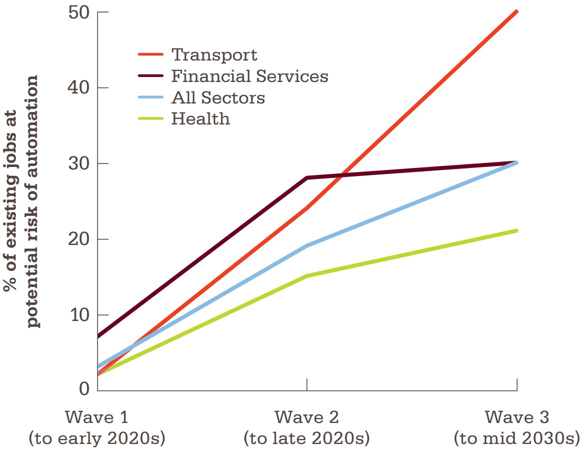
PricewaterhouseCoopers[4] has looked closely at how and where computing power can make existing human roles redundant. Importantly, it concludes that it is not just in repetitive manual labour, but also in clerical and professional roles (where access to a body of knowledge is required) that roles will change. It has estimated that up to 14% of global GDP will be affected by 2030 (US$15 trillion at today's values). In a survey, it found that 37% of all workers were concerned about losing their jobs.

The detailed analysis, however, showed that the absolute maximum would be somewhat less than this (about 30%) and that there would be two key mitigating factors which make it even less:

- The estimates are based on the technical feasibility of automation. In practice, 'economic, legal, regulatory or organisational constraints' will make the actual number smaller.
- Increases in human roles in some sectors due to overall rising income and wealth. They highlight 'non-tradable service sectors' such as education, health and personal services.

This provides a useful reminder of what automation and autonomy can offer, which PwC predicts will come in 'waves' of substitution. A good example of Wave 1 disruption is the Amazon Go store in Seattle, which has removed the need for checkouts by using an app on a smartphone to cover all purchases from the store.

Figure 2: Potential job automation rates by industry across waves[4]



Waves	Description and impact
Wave 1 Algorythmic wave (to early 2020s)	Automation of simple computational tasks and analysis of structured data, affecting data-driven sectors such as financial services.
Wave 2 Augementation wave (to late 2020s)	Dynamic integration with technology for clerical support and decision making. Also includes robotic tasks in semi-controlled environments such as moving objects in warehouses.
Wave 3 Autonomous wave (to mid 2030s)	Automation of physical labour and manual dexterity, and problem solving in dynamic real-world situations that require responsive actions, such as in transport and construction.

PwC sectoral analysis, however, provides the insight as to what action needs to be taken. Clearly different sectors are impacted differently, and hence if employment is to be maintained, then employees may well need to transfer between sectors during their lives.

The UK Industrial Strategy[6] does indeed refer to a new 'National Retraining Scheme' to address the needs of change caused by automation. The scheme will be informed by 'career learning pilots' which will test barriers to adults getting involved in learning. The initial investments however, about £1 per person in the UK, are inappropriate compared to the need for maybe one third of the population to be looking for redeployment. The Industrial Strategy also refers to the need to generate new ideas for new products and services in this new economic and business environment, and for this significant research & development funding would be needed from Government and industry, to keep the UK ahead in key technologies that are vital in the era of automation and autonomy. **IMechE recommends that the current UK Government Industrial Strategy increases its emphasis on research & development, skills and lifelong learning, as part of its Grand Challenge to put the UK at the forefront of artificial intelligence and the data and automation revolution.**

Figure 3: Occupations at highest risk of substitution by digital technologies[4]

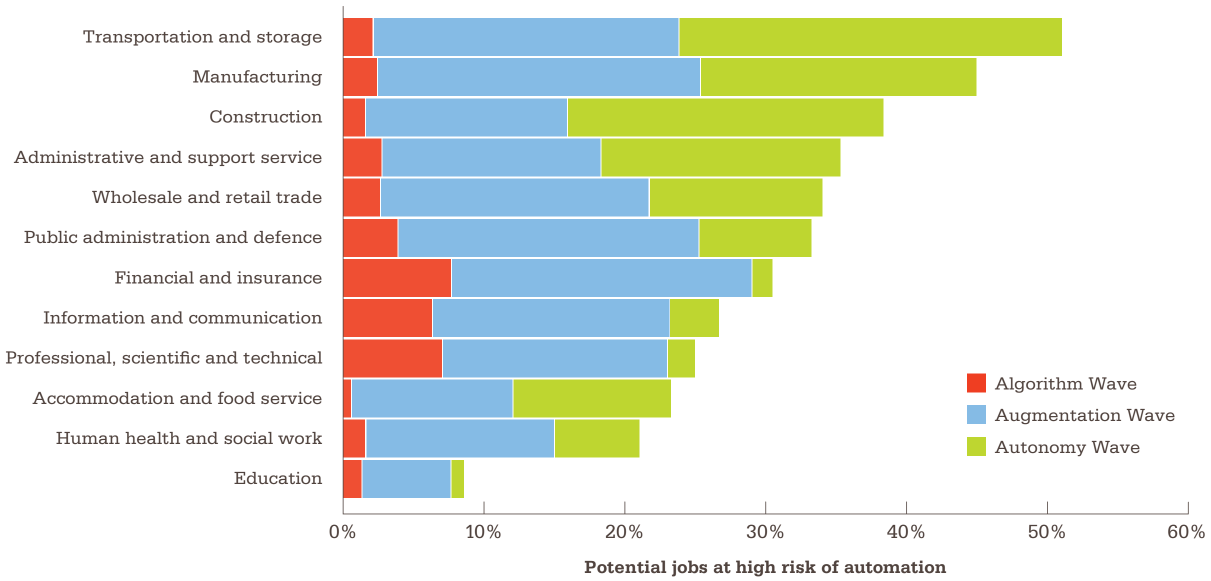


Image: Automated storage with manual packing in Amazon warehouse[8]

Manufacturing

The concept of robots in manufacturing has moved on since the introduction of machines for repetitive tasks at the end of the last century. That's not to say, of course, that robots cannot still be dextrous. Increasingly complex examples are possible, as shown by the shoe manufacturer Keen using two robots in conjunction to 'knit' a pair of shoes[7].

However, nowadays, robots are more likely to be seen in collaboration with humans, where the combined skills of both lead to further increases in productivity. An example is the Amazon warehouse[8] where robots simply move standard containers to and from work areas and store areas. The people in the work areas can then 'pick' those items from each of the standard containers as they arrive at the work area. Not only does this reduce the time to package an order, it allows the robot the freedom to choose where to store items based on the frequency with which they are selected.

Even closer interaction can be achieved, where the picking or lifting of the item can be performed by the robot to act effectively as an extra pair of hands.[9] Such 'cobot' activity relies on the machine itself being developed with extra sensors and protection that means it can be used unguarded. A company active in this area, Rethink Robotics, has named one of its machines Sawyer ('saw you') to emphasise that this awareness and safety protection are designed in.

The ability to sense the environment can also lead to increased safe use of 'lights out' working where machine tools can be fed, for example, using a cobot. Rapid-Line is an example of a metal fabricator in the USA using a two-armed cobot to allow unattended operation, potentially through the night.[10]

The increased use of sensing and AI has also been the subject of EU research through a project called PicknPack.[11] The aim of the project was to develop a machine that could make a variety of package sizes for fresh fruit and vegetables that could quickly cope with product changes. It was created to be able to pick target quantities from incoming crates, create a package suitable in size, and then pack and label them ready for despatch. A particular feature was its modular mould for vacuum-forming the packaging.

Image: Automation at BMW plant in Spartanburg

Once ready for despatch, it is increasingly possible that delivery in the future might be by drone. There are some key issues concerning air traffic control, and indeed theft, with individual potentially valuable packages flying around. A recent development however, Altitude Angel,[12] has been designed to encode all the restrictions associated with low-level flight in any chosen zone of operation. Route selection and coping with weather can therefore be combined with a knowledge of the permissible behaviour in a way that ensures compliance. Strangely, it is no easier with delivery on the ground; with a recent trial in Greenwich[13] using land-based rovers, as much time was spent thinking about security as about the complexity of crossing roads and navigating other obstacles.

The most recent round of research announced in a funding round in June 2018 by the EPSRC on digital manufacturing,[14] includes not only what might be expected in driving forward AI for process control, but also £1.6 million for a project entitled Digital Manufacturing on a Shoestring. Led by Cambridge University with 13 other partners, the project will address a concern that many digital developments are unlikely to be accessible to SMEs, due to the capital costs of computing and communication. It will seek to exploit very low-cost technologies already available for mobile computing. Stretch targets for the programme include the introduction of low-cost product tracking, exploiting emerging industrial Internet of Things platforms, and AI-based flexible control using commercially available AI and voice recognition software.

Image: Trial drone delivery of package using Altitude Angel[12]

Process Control

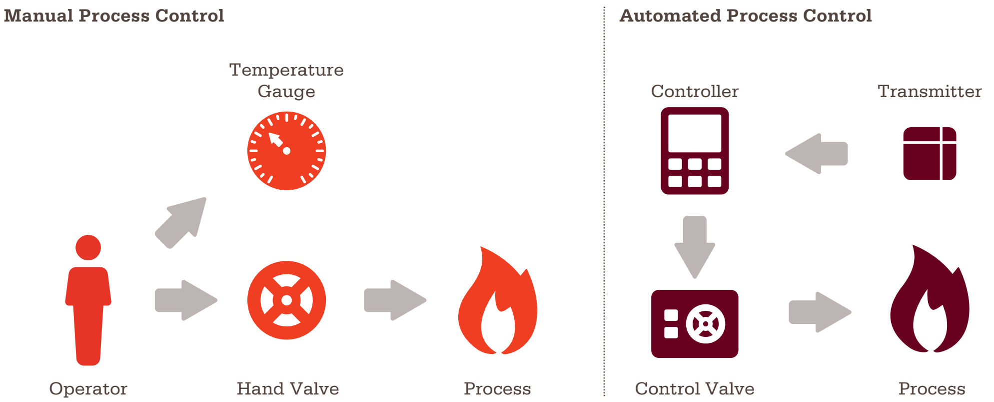
It is a far from new idea to use computers to control operating equipment. Supervisory Control and Data Acquisition (SCADA) has used computers networked with programmable logic, and discrete proportional, integral, derivative controllers, for many years to control plant and machinery. The first generation of systems in the 1970s relied on large mini-computers, and were independent standalone systems with no connectivity, operating as much for data acquisition as for limited control to pre-set parameters.

The latest systems can access data from multiple sites and multiple processes to enable more intelligent decision-making across more functions. Again driven by increased computing power, the list of functions under automatic control continues to grow, while those that are merely designed to send 'alarm' for human intervention continue to fall.

The key outcome, is that fully remote operation is now becoming increasingly possible. Indeed, it has been suggested that fully autonomous control of a nuclear power plant could well be feasible at some time in the future.[15] Not only would this make for cheaper operations when the plant itself needs to be some distance away from people and other facilities for safety reasons, but it would also work to reduce the impact of human error in its operation.

Analysis of most large accidents and disasters highlights the coincidence of a number of factors which lead ultimately to the destructive severity of the incident. These are often combined with poor human decision-making under pressure, or decision-making by humans of different skill levels. Both of these are clearly avoided if the system is being operated autonomously. Analysis of what went wrong at the Chernobyl nuclear plant in 1986 serves as an example.[16] The largest nuclear power plant disaster in history occurred during an important trial to see how the plant would react if its electricity supply failed. Three previous trials from 1982 to 1985 had operated without any incident, but they showed that the plant was not capable of handling such an eventuality. The 1986 trial was therefore a further attempt to find a way that it could. During all these trials, a number of automatic safety systems had to be disengaged to enable the reactor to be prepared for the simulation. At the time of the explosion, when the reactor was unstable and generating 33GW thermal power (over ten times its normal operating output), only 12 of the 211 control rods were still under automatic control.

Figure 4: Comparison of simple manual and automated process control to a set point



There are clearly, however, many less safety-critical, but profit-enhancing, uses of digital technologies. A review by McKinsey, Smartening up with Artificial Intelligence, from April 2017[17] suggested they could be categorised as:

- Enhanced predictive maintenance
- Collaborative and context-aware robots
- Yield enhancements in manufacturing
- Automated quality testing

The review profiled how companies such as Neuron Soundware used 'artificial auditory cortexes' to simulate human sound interpretation, thus automating and improving the detection and identification of potential plant breakdowns. In a similar way, KONUX[18] uses vibration sensors to detect anomalies in railway lines. Both use machine learning to identify relevant features in the data – often during 'supervised learning' where humans input relevant failure behaviour that matches the data – and hence improve accuracy.

It is interesting to note, however, that systems are still predominantly automatic rather than autonomous. The ability to take remedial action remains a human function. Indeed, the optimisation of the system, eg in defect detection, relies on human input to reduce the number of false positives over time. The benefits, however, are great. McKinsey claims that up to 50% productivity increases can occur because of more focused use of skilled labour, and improvements of up to 90% in defect detection using deep-learning based systems.

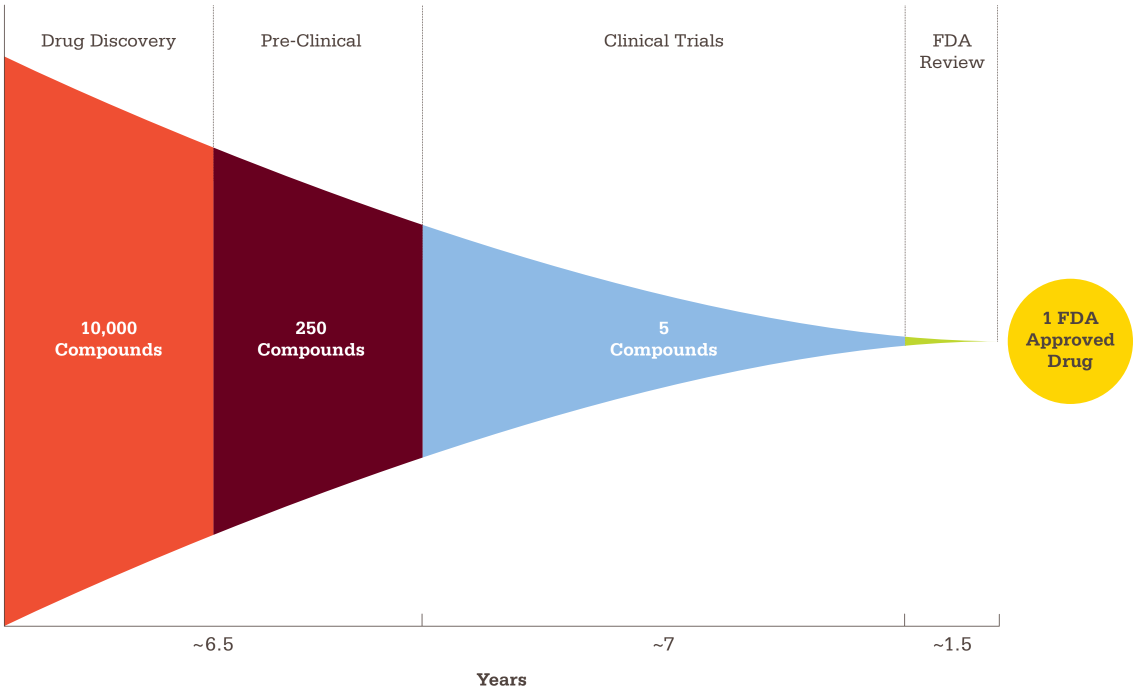
It seems clear therefore that skilled labour, able to interact with and benefit from the digital system, will continue to be needed for the long term. Indeed the current shortages of such skills suggest that we may well be 'behind the curve' when it comes to growing the digital sector in the UK. There are many useful skills programmes already in place (eg Skills for Londoners[19]), but they are broadly agnostic on subject, or generic at best. Success will need the inclusion in the education system of those growth companies, often SMEs, to ensure that the industry perspective is clear and able to be satisfied. UK Government is already investing significantly via Innovate UK to grow specific businesses; it now needs to engage those existing projects with the education system to ensure that they can gain the skills they need to grow. **IMechE therefore recommends that Innovate UK investments in digital technology, especially the Digital Catapult, the High Value Manufacturing Catapult and the Knowledge Transfer Network 4Manufacturing, are incentivised to work with schools, colleges and universities to strengthen the links between the needs of the digital economy, and current teaching and learning.**

Healthcare

Life expectancy worldwide continues to increase, as does the expectancy that treatments will be available for every ailment. During the 19th and early 20th centuries, our health benefited from improvements in sanitation, housing and education, causing a steady decline in early and mid-life mortality, which was chiefly due to infections. This trend continued with the development of vaccines and then antibiotics. By the latter half of the 20th century, there was little room for further reduction in early and mid-life mortality. The continuing increase in life expectancy is now due almost entirely to a new phenomenon: the decline in late-life mortality.

The challenge is that drug-assisted healthcare is increasingly slow and expensive to develop. There is not perceived to be any 'silver bullet', but instead an increasingly fragmented and personalised treatment for increasingly individualised conditions. There is indeed a moral dilemma as to whether there is any return on investment for drugs to be developed for certain diseases. The value of AI to work through the predicted behaviour of many millions of different compounds is therefore a valuable tool in shortening the time and reducing the cost of each drug discovery.

Figure 5: Drug discovery and development timeline[20]



A number of UK-based organisations are active in this field. BenevolentAI[21] has adopted the approach of uploading every piece of information it can find in a certain area and then looking for insights through being able to handle such large datasets and volumes of information. GTN, on the other hand, has a focus on finding and optimising leads through advanced quantum-based representation of molecules, and efficient machine learning for searching and sampling astronomically large search spaces of small-molecule drugs.[22] As a result, it is one of four start-up companies that have been given access to the Digital Catapult's considerable computing power in its Machine Intelligence Garage. As highlighted by the Digital Catapult,[23] it is often access to affordable super-computing power that can be the largest barrier to innovation.

Automation and autonomy in a healthcare laboratory, however, is nowhere near as visible as it is in patient care. Japan in particular has invested heavily in creating automaton robots that can welcome and pre-screen enquiries for business, but also medical treatment. Pepper by Softbank Robotics[24] is a genuine cobot that modifies its behaviour based on its interaction with humans. Limited at the moment to offering directions rather than diagnosis, it can adjust its delivery to the mood indicated by the patient's facial expression and body movements. It is claimed that it can understand 20 different languages.

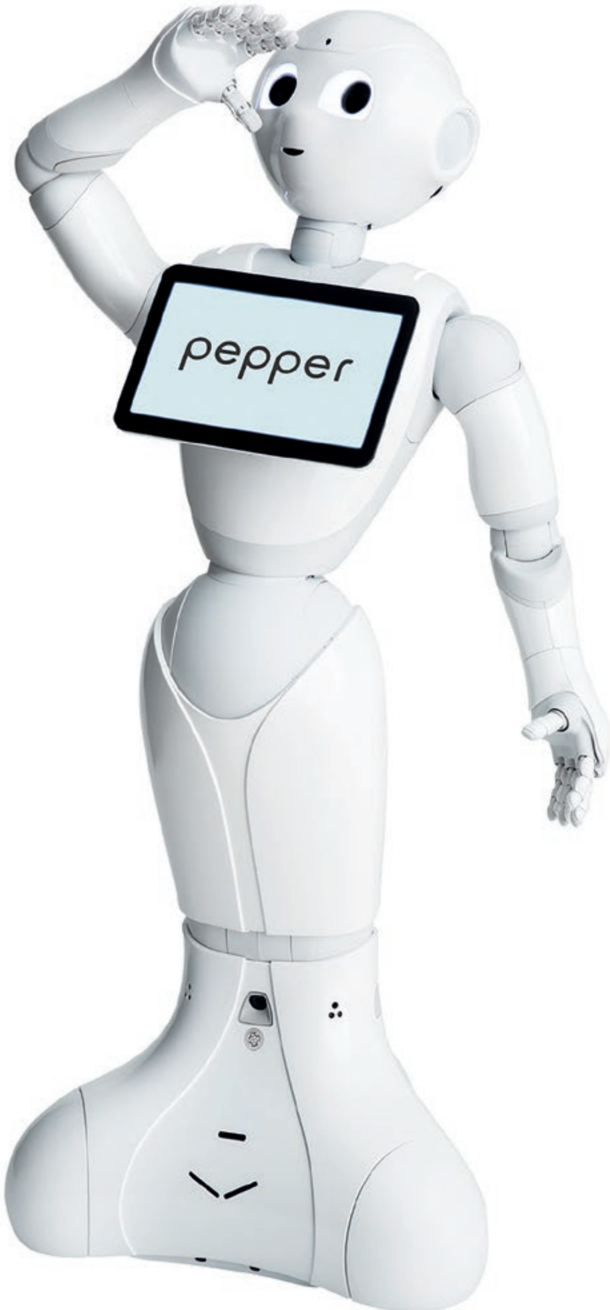


Image: Pepper Robot by Softbank Robotics[24]

Early attempts at automation in healthcare are, however, already being made at diagnosis, based on a smartphone application. GP at Hand[25] offers an initial screening by a question-and-answer session, which can be followed up by a request to make a facetime appointment with a GP, or indeed a physical consultation with another doctor at one of five locations across London. But while anyone can join its service, the website says it may not be suitable for 'complex mental health problems or complex physical, psychological or social needs'. NHS patients participating in this system have to transfer completely from their previous GP to be able to use it; this could mean that potentially the five physical clinics have to provide a lot of the care needed by their 575,000 users, rather than this being an entirely online service.

Image: Cyberdyne HAL Assistive Limb[27]

Pushing further automation, Woebot[26] is another smartphone application, which offers a series of responses based solely on cognitive behaviour therapy for those patients suffering with anxiety and depression. It remembers all interactions and offers the potential to customise its behaviour based on the user's behaviour. Woebot is not claimed to be a replacement for an in-person therapist. It is, however, part of a widening array of approaches to mental health. Before it was launched, it was tested on 70 college students who had reported symptoms of depression. They were split into two groups – one was assigned to chat with Woebot over two weeks, while the other was directed to read an e-book about depression. The students using Woebot said they saw a significant reduction in their depressive symptoms, unlike those in the e-book group. They also reported chatting with it almost daily, even though they weren't required to spend any specific amount of time with it. Currently Woebot sends approximately 2 million messages a week to users in 135 countries.

Physical (mechanical) care is rather easier to see and can bring immediate benefits. There are physical aids for lifting such as Cyberdyne's HAL (Hybrid Assisted Limb) range.[27] The equipment helps workers lift, move and monitor residents by responding to bioelectric signals from the wearer's body. Beds that can morph into wheelchairs, sensors that can detect when a patient moves near the edge of a bed and is in danger of falling out, even sensors to monitor intestinal movements to predict when someone needs the lavatory, have all been developed and trialled.[28]

It is perhaps in surgery, however, where automation (not autonomy) is gaining most acceptance. Despite the public concern over being ‘operated on by a robot’ shown earlier, the use of assist devices is becoming widespread in operating theatres. Already, over one quarter of NHS hospitals which perform operations, use them. Some of them are simply sophisticated tool holders like FreeHand[29] which can reposition itself based on head movements of the surgeon, and hold a camera steady without tiring; this supports minimally invasive surgery. Others such as da Vinci[30] are typical of remote handling equipment used in other industries, albeit here on a very small and sterilisable scale.

Health, however, is a very sensitive issue. While it is accepted that no-one can live for ever, the involvement of digital technology in care that then doesn’t achieve the desired outcome brings in a further factor for concern. There are strong parallels with the introduction of semi-autonomous vehicles on the road. Each accident and certainly each fatality brings a close level of scrutiny as to whether the technology was at fault. Also, as with vehicles, and highlighted in IMechE’s case study on Autonomous and Driverless Cars,[31] there is a question of liability perhaps falling on the software developer or the hardware manufacturer, as much as the user of the equipment. In all cases where autonomy of automated systems is increased, there will need to be a radical change in the legislative framework around these systems to ensure they are used safely and responsibly.

Image: Intuitive Surgical's da Vinci Robotic Surgery System[30]

Already with healthcare, there are critical comments claiming increased risk from even the robotic assisted surgery common now for gynaecology. The 'report card' below was created by an organisation with a competing form of surgery.[32] The original peer-reviewed paper it is based on, however, said "…as reporting in the MAUDE system is voluntary, the true incidence is unknown. Compulsory reporting would allow identification of absolute risks associated with robotic surgery and lead to improved root-cause analyses."[33]

Similarly, the Daily Telegraph[34] reported that "researchers at Stanford University School of Medicine in the US reviewed nearly 25,000 operations across 416 American hospitals between 2006 and 2012 and found that just 28% of kidney removal patients who had keyhole surgery performed by a human surgeon were under the knife for more than four hours, compared to 46% of those who were operated on robotically." The implication is that robotic surgery is not beneficial because robotic surgery lengthens the time under anaesthesia, meaning that the added benefits do not outweigh the added risks.

The actual source article, however, gives further detail by saying that, "Some procedures, such as the removal of the prostate or the removal of just a portion of the kidney, require a high degree of delicate manoeuvring and extensive internal suturing that render the robot's assistance invaluable. But Chung and his colleagues wondered whether less technically challenging surgeries, such as the removal of a whole kidney, may not benefit as significantly from a robot's help."[35]

It is clear that digital technology and especially AI cannot be 100% accurate. They are bound to contain errors and make mistakes. The challenge is to ensure fair evaluation, especially where human life is at risk. It is as easy to be overly enthusiastic as it is to be overly critical. There would appear to be a key role for the public understanding of risk specialists to advise and contribute to the way in which data is presented and analysed. **The Institution of Mechanical Engineers therefore recommends that a campaign of public engagement, building on Year of Engineering 2018, is created to increase public understanding, and also influence Government and industry policy regarding the future development and adoption of automation and autonomy for societal benefit.**

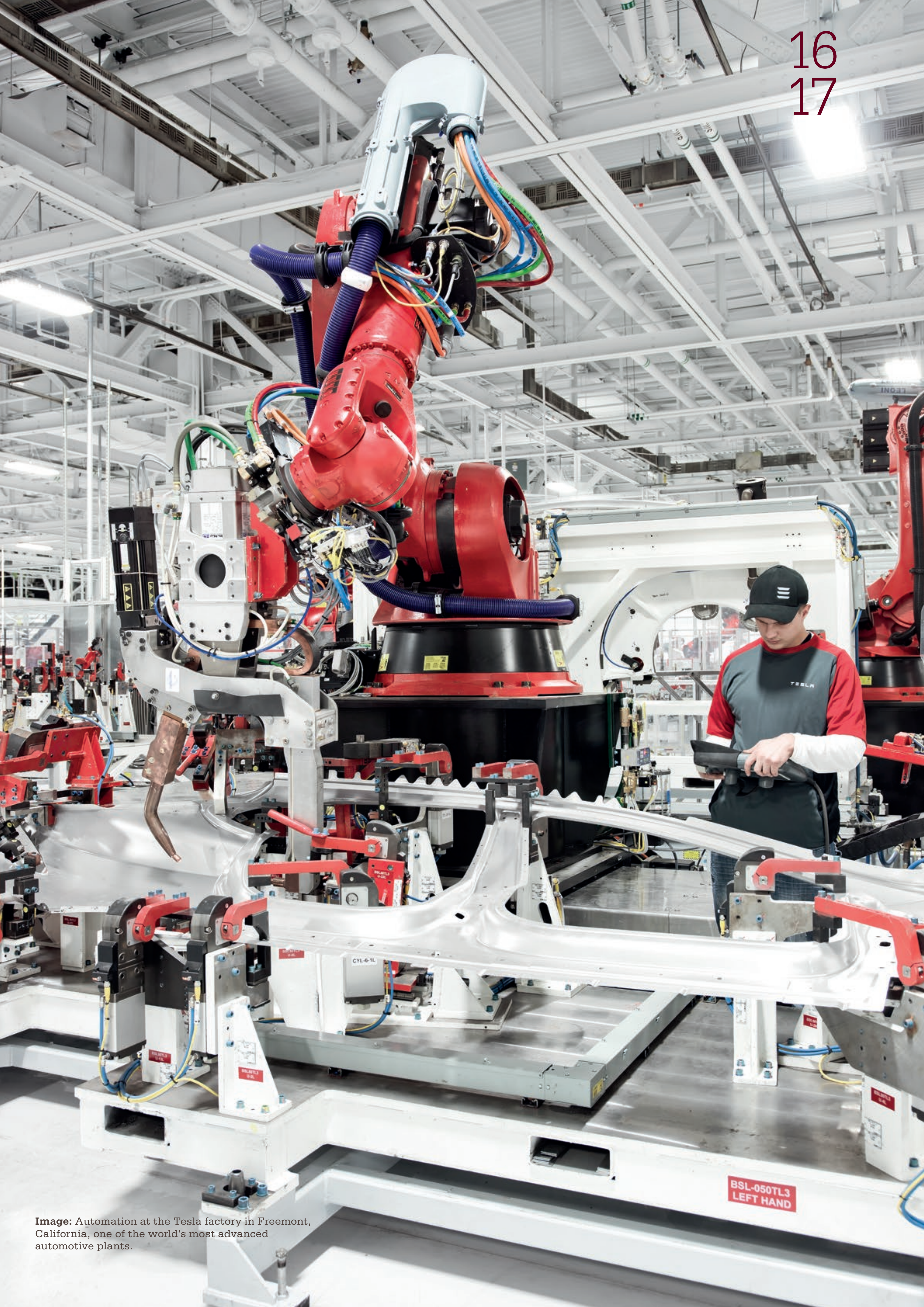


Image: Automation at the Tesla factory in Freemont, California, one of the world's most advanced automotive plants.

Potential Future Predictions

Business clearly has an overall positive view of the potential benefits coming from increased automation and especially autonomy. On the AI section of its website, the international management consultancy and business services company, Accenture, has a list of 30 links to different articles all in support of 'How artificial intelligence will amplify people, products and business'.[36] It summarises AI as being the product of 'transformation of the relationship between people and machines' with 'reimagined business models' and 'unlocked trapped value in data'. It reflects some PricewaterhouseCoopers work from April 2017[37] which predicted significant increases in the use of connectivity and data analytics over the next five years.

Figure 6: Job elements at risk from substitution over 5 years, 10 years and 20 years[4]

	In use today	Change over the next 5 years	In use in five years
Predictive maintenance	28%	+38%	66%
Big data driven process and quality optimisation	30%	+35%	65%
Process visualisation/automation	28%	+34%	62%
Connected factory	29%	+31%	60%
Integrated planning	32%	+29%	61%
Data-enabled resource optimisation	52%	+25%	77%
Digital twin of the factory	19%	+25%	44%
Digital twin of the production asset	18%	+21%	39%
Digital twin of the product	23%	+20%	43%
Autonomous intra-plant logistics	17%	+18%	35%
Flexible production methods	18%	+16%	34%
Transfer of production parameters	16%	+16%	32%
Modular productions assets	29%	+7%	36%
Fully autonomous digital factory	5%	+6%	11%

Other work of PricewaterhouseCoopers[4] presents perhaps a wider view, by acknowledging that the pervasive nature of increased automation will mean job losses as well as job openings. It takes a generic approach by showing that it will be certain tasks, rather than specific occupations, that will be under threat. In a way, it shows that no job role will be immune, but that some are clearly much more likely than others to disappear. Importantly some roles, eg computation, are easier to substitute and hence will disappear sooner (within the first 'wave ' over the next five years), while others involving more complex manual tasks, or social and literacy skills, will take longer (over 20 years).

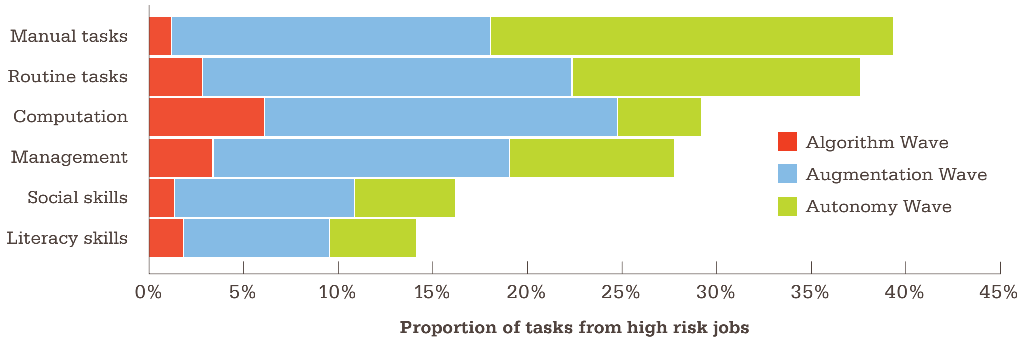
Public acceptance and indeed encouragement will be crucial. In a survey of 3,938 people worldwide in 2017 entitled Awareness, Acceptance and Anticipation of AI, ARM reinforced the current view that positive expectations of benefits outweigh the risks.[38] Its survey was only of people who thought that AI would make an impact, but of those 61% thought it would be for the better (with 22% worse and 17% just different). They confirmed what has been the theme of this case study, that the largest effects on public interest will be in healthcare, with manufacturing and economic growth coming in second and third.

Those hoping to profit from automation and autonomy are therefore pushing at an open door. There are public concerns, mostly about security and privacy, but the focus for the moment seems to be on what can be gained, not lost. A surprising number in the ARM survey were not yet aware (and hence not concerned) that AI was being used by familiar brands like Spotify, Netflix and Facebook to drive up engagement already. The key challenge, and hence the recommendations from IMechE, relate to ensuring this good relationship continues. If it does, it will surely rely on increasing public familiarity with the technology, at the same time as offering opportunities to take part in the changes it brings.

Table 2: Public expectations of the top benefit likely to come from AI [4]

Benefit	**%**
Advancements in areas that help humans eg medicine and science	37%
Tedious or dangerous tasks	29%
Lower business cost or increased capability leading to better service and lower prices for consumers	19%
Less chance of human accidents	11%
More free time for humans	5%

Figure 7: Job elements at risk from substitution over 5 years, 10 years and 20 years[4]



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