Technology and the future of the government workforce

How new and emerging technology will change the nature of work in government

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About this report

New and emerging technologies will change government in a wide range of ways. They will make it easier to do many tasks quicker, more cheaply, and on a greater scale than ever before. Significantly, these technologies have the potential to automate large swathes of cognitive work. And in doing so they will transform the workforce that is currently performing these tasks. We do not expect that these waves of automation will drive mass redundancies within government; technology is more likely to augment the work done by officials, rather than replace them. Managing this transition will require new approaches and new ways of thinking about capabilities within government.

The government is already beginning to experiment and innovate with these technologies, but their adoption is far from widespread. Crucially, they do not have to force the government to choose between being more effective or efficient. With careful planning and management this transformation could return the benefits of both. In this report we assess the state of this transformation, what it means for the government workforce, and what steps the government needs to take now to ensure that it manages it successfully.

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Foreword

As the coronavirus pandemic evolves from crisis response to a new reality, governments around the world are shifting their focus from the immediate to the recovery that must follow. Economies everywhere are under extreme strain, government resources are limited, and the demand for support and services is high and rising. Technology will offer new tools that governments can use to address these challenges. The choices that governments make now will have far-reaching consequences.

New and emerging technologies are playing an important part in this recovery, from novel digital public services to new ways of remote working within government. While technological change is already happening, it is still a process that governments can shape. The choices they make about how to use these new technologies will have long-term implications for government itself and society. This report looks at the current and future role that technologies will play within government and what this means for the future of the government workforce. At the same time the government is looking at the organisation of the civil service with a mind to reforming it. Technology will play a key role in any effort to transform how government works, to make it fit for the challenges of the future.

Emerging technologies offer many new ways to automate work within government – in particular many forms of cognitive labour that have previously not been conducive to technological automation. Data gathering and analysis, responding to customer requests, and many routine business functions in finance and HR are some of the types of work that will be changed by novel technological automations. Applications of these technologies could help the state to be more efficient, reducing the amount it spends on people in an era when public finances are tight.

Efficiency is not the only benefit. New technologies offer many ways to make the work of government more effective. Government organisations can use automations and other advances to deliver better outcomes for the same cost. This will be vital in an era of increased demand for public services, government information and support.

There are many potential applications of new technologies within government. They will help improve how data is analysed, how policy is made (itself the topic of a recent Institute for Government report), how public services are delivered, how governments engage with the public and how government facilities are kept secure. In many of these instances the tasks that technologies will do, or help do, are currently carried out largely by people. It is vital that government organisations understand what this technological change looks like, and how it will change their workforces.

Bronwen Maddox, Director, Institute for Government

Summary

From the printing press to the personal computer, new technologies have always changed the way government works. And while new technologies can present governments with new headaches, from data wipes to cybercrime, the benefits are many. These include greater personalisation of public services, more accurate forecasting of future events, trends and behaviours, and the means to simulate and test new policies before implementing them.[1]

A recent example, NHS Test and Trace, while beset with teething issues, shows the potential of new technology to help tackle the defining crisis of our times in coronavirus – while large numbers of civil servants working away from Whitehall shows that a shift from traditional working practices is possible.

Outside of the pandemic response, new and emerging technologies, such as AI, are offering governments new ways to carry out tasks as varied as mapping conflict zones to identifying fraud in food supply chains.[2,3,4] But the rapid development of new technologies requires governments to make choices about how they will use them. These choices will have lasting impacts on how the government operates, and in particular its workforce. Computers will not replace civil servants. But the use and influence of new technologies in government will profoundly change almost every role in government in one way or another. This report considers that change, and how decision makers can make the most of what technologies have to offer. Our focus is primarily on the skills civil servants need, how effective they are in their roles, and how many people are needed to carry out the government's work. A recent Institute for Government report specifically considers the opportunities new technologies present for policy making.[5]

Coronavirus is not the only factor prompting change in the civil service's working practices, and workforce. New reforms spearheaded by Dominic Cummings, Boris Johnson's influential former special adviser, have returned long-standing questions of technology, modernisation and government work to the front of the debate. These begin with some hard questions:

- What exactly is the government's skills base?
- How will technology change this?
- What new opportunities are being created by technology?
- How do the existing structures of government help or hinder this transition?

The government has not shown itself to have answers to these questions. Few published strategies or annual reports make any reference to automation, which is among the least 'advanced' of the changes new technologies are likely to bring, while others do not go anywhere near far enough to meet the current government's rhetoric on technological change.

But there is time for the government to set itself on a good path to new ways of working. To do this, government leaders need to identify their management ambitions, to decide if effectiveness – using technology to work better – or efficiency – using it to work cheaper – is the principal aim. New technologies offer both, but as in other areas of government work, such decisions will involve hard choices.

Government jobs are less at risk than others across the economy

Where previous technological revolutions have reshaped the world by introducing technologies that automated the manual tasks that defined many jobs, today it is cognitive work that will be transformed. Tasks such as financial audit, handling customer requests and data analysis will increasingly be performed by machines. Roles that include these tasks are more likely to be augmented by technology (possibly making the lives of workers easier) than replaced by it.

The possibility of wider automation has, however, led to fears about job losses. In 2019 the Office for National Statistics (ONS) estimated that across the whole of the UK economy 7.4% of jobs were at high risk of being automated out of existence.[6] Other studies make even more extreme predictions, suggesting that up to around half of total employment is at risk from automation.[7]

But most of the types of job that are at risk of being made redundant through technological automation, while common in the economy at large, are uncommon in government. Some of the most vulnerable occupations are waiters and waitresses (73% of UK jobs at risk), supermarket shelf fillers (72%), bar staff (71%) and retail cashiers (65%).[8] Conversely, some of the occupations least at risk are firmly in the public sector or central government. These include research and development managers (22%), solicitors (23%), actuaries, economists and statisticians (23%), and chief executives and senior officials (24%).[9]

Some government jobs will be vulnerable – organisations such as HMRC and HM Land Registry are already replacing contact centre operators with chatbots – but for most roles new technology will bring change, not redundancy.

Machines can work at a scale and pace that humans cannot match, and will take over many tasks that are currently rote and time consuming. For instance, the Ministry of Justice (MoJ) recently piloted the use of robots to process simple administrative tasks such as processing requests for parental leave. Other departments have subsequently adopted this useful automation.

In other cases machines will take on tasks that were otherwise not being done because they required a prohibitive amount of resources, or were considered unsafe for people. The Driver and Vehicle Standards Agency uses algorithms to search automatically through vehicle testing data to identify likely cases of MOT fraud (where garages approve vehicles illegally). The results from the algorithm are used to target inspections. Elsewhere, governments will take advantage of machines to perform tasks that were previously difficult, impractical or otherwise dangerous for human workers. For example, National Grid is now using drones, rather than people, to inspect power lines, and the footage is further analysed using machine learning to reduce the amount of work that its staff need to do.[10]

This will free these workers to focus on the aspects of work where machines are weaker – and will probably remain weak for the foreseeable future. These include tasks that involve creative or abstract thinking, planning for the future or interacting with others. Running focus groups, say, will remain with humans for the foreseeable future, or managing a team that is delivering a new public service. Enabling a workforce to devote more time to these types of task could reap rewards for government.

New technologies will also create jobs. This is already happening – for example, the Civil Aviation Authority has had to develop entirely new capacities to serve as a regulator of drones.

Government leaders will have to balance efficiency and effectiveness

These new technologies present leaders with a choice. They can embrace the automation of routine tasks to help their workforce focus on other more complex tasks. This could help to make government more effective – the MoJ has, for example, installed 'digital kiosks' in prisons that allow prisoners to submit requests for various needs without involving a prison officer. This is a form of automation that frees up prison officers' time to focus on other tasks that machines cannot do, such as safeguarding inmates.

Equally, organisations could embrace automation to deliver efficiencies. Several government organisations are already replacing contact centre workers with chatbots to deliver efficiencies – HMRC had 78 robotic processes in place by 2019, which handled more than 15.7 million transactions that would have previously required a human worker.

There will be a case for both approaches – especially given the stresses coronavirus has placed on both government services and public finances – and government organisations will need to decide which to apply in different areas of their work. How they choose will depend on the nature of the organisation and its leadership, the technology available, and the specific pressures and agendas of the day. This will be a balancing act. What matters is that government leaders, including senior ministers and permanent secretaries, consider future skill needs now, and avoid creating dependencies on 'legacy skills' (whose only purpose is to maintain old or outdated systems) at the expense of valuable advancements.

Existing government plans to manage this change do not go far enough

The Civil Service Workforce Plan 2016–2020 made only a single reference to automation – referencing how HMRC has automated some mailing processes.[11] Few government organisations are sufficiently prepared for such technological change. This is understandable: many of the technologies described in this report (a list of these is given in Appendix A) are novel and often not yet fully mature, and organisations are still understanding how best to use them, now or in the future. Given the imminence and likely scale of change that these technologies will bring, government organisations will not be able to avoid this issue for much longer.

The scale and heterogeneity of the individual workforces of the many organisations in government makes exact planning difficult. Progress made by organisations like HMRC and HM Land Registry shows it is not impossible. But most are yet to plan for the full impact of new technology on the government workforce in any meaningful way.

This is an omission, and one that carries with it additional risk at a time when normal working practices, inside and outside of government, are being disrupted by coronavirus. The following are the Institute for Government's three key recommendations to guide governments in the near term as it grapples with the impact of technology on its workforce:

Recommendations

1. **The government must develop a new overarching strategy for the future of the civil service workforce.** The government needs an overarching strategy that clearly articulates how technology supports its vision for the future of the civil service. The Cabinet Office and Civil Service HR should build on the ideas put forward in the Civil Service Workforce Plan 2016–2020, the Government Technology Innovation Strategy and the National Data Strategy, among others. It can draw from these to set a new high-level direction for all government organisations.

2. **All government organisations should develop independent and individual workforce plans that outline how they will manage specific aspects of technological change relating to their own workforce.** All government organisations need to have their own new workforce plans in place. These plans must provide a detailed description of their current workforce and the one that the organisation expects it will need in the coming years, based on political priorities and existing business plans.

3. **Functions and professions need to play a bigger role in co-ordinating technological and workforce change across government.** As individual organisations take a lead on specific elements of workforce planning, the functions and professions need to expand their role to help to co-ordinate the response to technological change across government. This will involve providing career support and development opportunities to government workers, especially those in roles which are common across many government organisations.

Introduction: Technological revolutions and government

The last lighthouse keepers in the UK retired on 26 November 1998, when North Foreland Lighthouse in Kent became fully automated.[12] These six men were the last in a long line of keepers to be discharged of their duty.[13] All keepers were government employees, working through the organisations of Trinity House and the Northern Lighthouse Board, public bodies sponsored by the Department for Transport (DfT).

Ensuring safe maritime navigation is a responsibility that the government has held for centuries – Trinity House itself was founded by royal charter in 1513.[14] However, the way the government has discharged this responsibility has changed over time. New technologies have expanded the scope of what was possible and, beginning with the automation of Oxcars Lighthouse in Scotland in 1894, changed the number and type of people required to do it.[15]

No single technology transformed lighthouses or the role of the lighthouse keeper. At Oxcars, a clockwork timing mechanism was used to automate the light, meaning that the two full-time keepers were no longer needed: the mechanism was wound weekly by the boatman who delivered the gas that fuelled the lamp.[16] The subsequent invention of the Dalén sun valve automated the light controls in all other lighthouses in the early 20th century.[*,17]

However, many lighthouses – especially in remote locations – still needed full-time keepers to perform maintenance. From the 1960s, new and improved technologies further changed the lighthouses and reduced their need for staff. Electrification and improvements to radios and telephones made it easier to monitor and control lighthouses remotely, while helicopters made it easier to access sites to perform maintenance when needed. Throughout the latter half of the 20th century, the role of the lighthouse keeper shrunk until, on that winter day in 1998, it vanished.

But the organisations that run lighthouses, and their work, continue. Today, Trinity House and the Northern Lighthouse Board employ around 450 staff between them.[18] A diverse mix of sailors, technicians, electrical and civil engineers, and others work to guarantee the supply of navigational aids. And technology continues to transform the lighthouses themselves – renewable energy sources such as solar cells and wind turbines, for instance, are powering an increasing number of remote installations. This story will play out time and again in government's relationship with technology.

* Gustaf Dalén would win the Nobel Prize in Physics in 1912 for the invention of the sun valve. In later life he would also go on to invent the AGA cooker.

Automating the lighthouses revealed that the real value of the lighthouse keepers was the work they did to maintain the facilities, not merely turning the light on and off. The same will hold true for many roles in government. Machines will do a greater share of tasks, but they will often be simpler and more routine, at least initially. This will make the work done by people in government more valuable, as they tackle the complex, non-routine tasks that machines cannot.

New technologies have always changed governments, from the printing press to the personal computer. They change the nature of the challenges that governments face, the tools they have to solve them, and the ways that they organise themselves and operate. This is no different today, in the age of e-passports, artificial intelligence and 'virtual parliaments'. But the main theme now is less about outright job replacement, and more about job change. While some jobs will go, others will emerge, particularly in areas such as technological regulation, and new forms of operational delivery that are made possible by new technology. For example:

- Regulators such as the Civil Aviation Authority and the Financial Conduct Authority are expanding as they take on new functions regulating the use of technologies such as drones and cryptoassets.

- The ability to do predictive maintenance is changing how the Ministry of Defence (MoD) services its large fleet of vehicles, and will also have relevance for how the government maintains other fixed assets such as buildings or other infrastructure.

There is a moment of opportunity here for government. Technologies such as AI, distributed ledgers, augmented reality (AR) and biometrics are still new. There is scope now for the government to shape their use, adoption and direction that will diminish as they become more established. Other countries are already racing to take a lead here. South Korea, Singapore, Taiwan and others have shown the potential of new technology to help with crises, such as coronavirus, as well as other long-standing policy challenges.[19,20] The full potential of these new technologies is only just beginning to be explored, but the government faces stiff international competition if it wants to keep up, let alone lead.

Government in the 21st century

According to the World Economic Forum we are currently in the 'fourth industrial revolution', a period broadly defined by the emergence of technologies that combine hardware (physical machines or devices), software (the programs that operate hardware) and biology.* Previous industrial revolutions, experienced between the 18th and 20th centuries, were marked by dramatic increases in worker productivity and efficiency, as machines adopted tasks that previously required a human to perform.[21]

* According to Klaus Schwab, who coined the term in 2015, the first industrial revolution harnessed the power of steam to mechanise production; the second used electricity to enable mass production; and the third used "electronics and information technology" to automate production. See Schwab K, 'The Fourth Industrial Revolution', *Foreign Affairs*, 12 December 2015, retrieved 22 July 2019, www.foreignaffairs.com/articles/2015-12-12/fourth-industrial-revolution

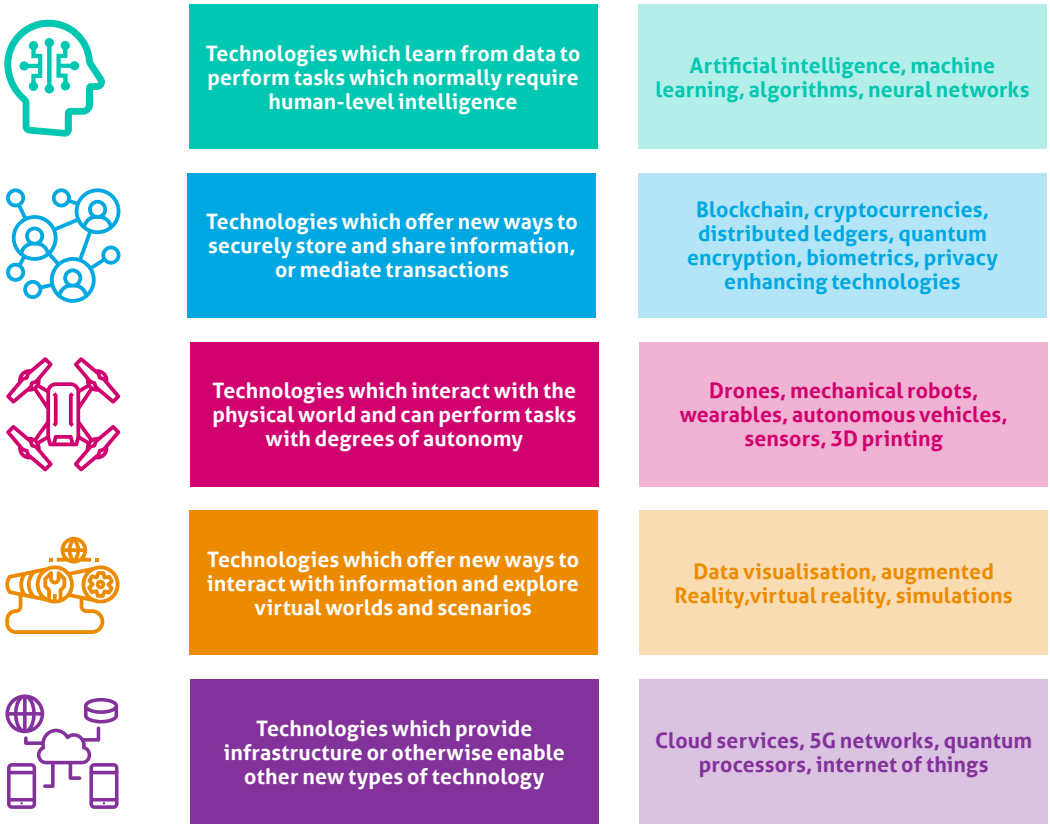
This century is different.[22] In the fourth industrial revolution we have technologies that can automate a broad range of cognitive tasks, such as interpreting text or manipulating data. While this is not the first time that technology has changed knowledge-based tasks, the scale of this change is unprecedented. This type of 'knowledge work' represents a substantial portion of the work done in governments, central and local, in every nation around the world.[23]

Choices that government leaders make about how and where to use these technologies will reshape not only the way work is done in government, but also the fundamental nature of what type of work government does. These choices will have a lasting impact on how government operates, and the workforce that it needs. Crucially, it is not just that government *can* make these choices, it will *have* to make them. Technologies continue to advance and it is increasingly hard for governments to ignore their impact – benefits and challenges. These include greater personalisation of public services, more accurate forecasting of future events, trends and behaviours, and better ability for policy makers to simulate and test new policies before implementing them.[24]

New technologies are already transforming the UK government

New and emerging technologies, such as artificial intelligence, are already offering ways to make government more effective.[25] In 2017, the Government Digital Service (GDS) identified more than 140 technology projects, using 27 types of technology, across central and local government.[26] These include an AI system for the Royal Navy that supports and co-ordinates decision making between ships in a fleet, distributed ledgers at HM Land Registry (HMLR) that securely track and store the sale of UK property, and automated customer service agents that handle applications for benefits on behalf of some local authorities.[27,28,29,30] Yet while the government references these new technologies in its future transformation and shared services strategies, the wider workforce issues that arise from their adoption have not been addressed.[31,32]

Figure 1 **Five main categories of new and emerging technologies**



Source: Institute for Government analysis.

1. Technology and jobs: the wider picture

Most studies agree that technological automation will change a significant number of jobs, and that the impact of this will be distributed unevenly across different sectors of the economy. The consensus is that certain types of job are most likely to be affected, and that these are typically based on routine tasks.[33] But while machines taking on work previously done by humans in, say, factories is not new, new technologies' ability to change cognitive work tasks is.

Some argue that this will lead to what John Maynard Keynes described as "technological unemployment".[34,35] The counter view, however, is that technology will be left to carry out routine tasks, albeit on an ever increasing scale, leaving people freer to focus on higher-value activities, such as research, planning, content creation, and management.[36] In this argument, machines will create a space for creativity that in fact drives job creation.[37]

New technologies will predominantly change how routine tasks are done

Every role consists of tasks, which can be broken down into two categories: manual and cognitive, which can then be split into routine or non-routine applications.[38] In general, routine tasks are easier to automate using technology.[39] General process automation (that is, without using AI) will transform many routine tasks.[40]

Figure 2 **Examples of types of task that are generally manual or cognitive and more or less routine**

	More routine	Less routine
Cognitive	Categorising information Screening job applications Auditing financial records Answering customer phone calls	Managing people Developing plans and strategies Negotiating contracts Drafting legislation
Manual	Mechanical assembly Patrolling or guarding locations Handling goods in warehouses	Physical care for others Mechanical repairs Arrest and detention of individuals

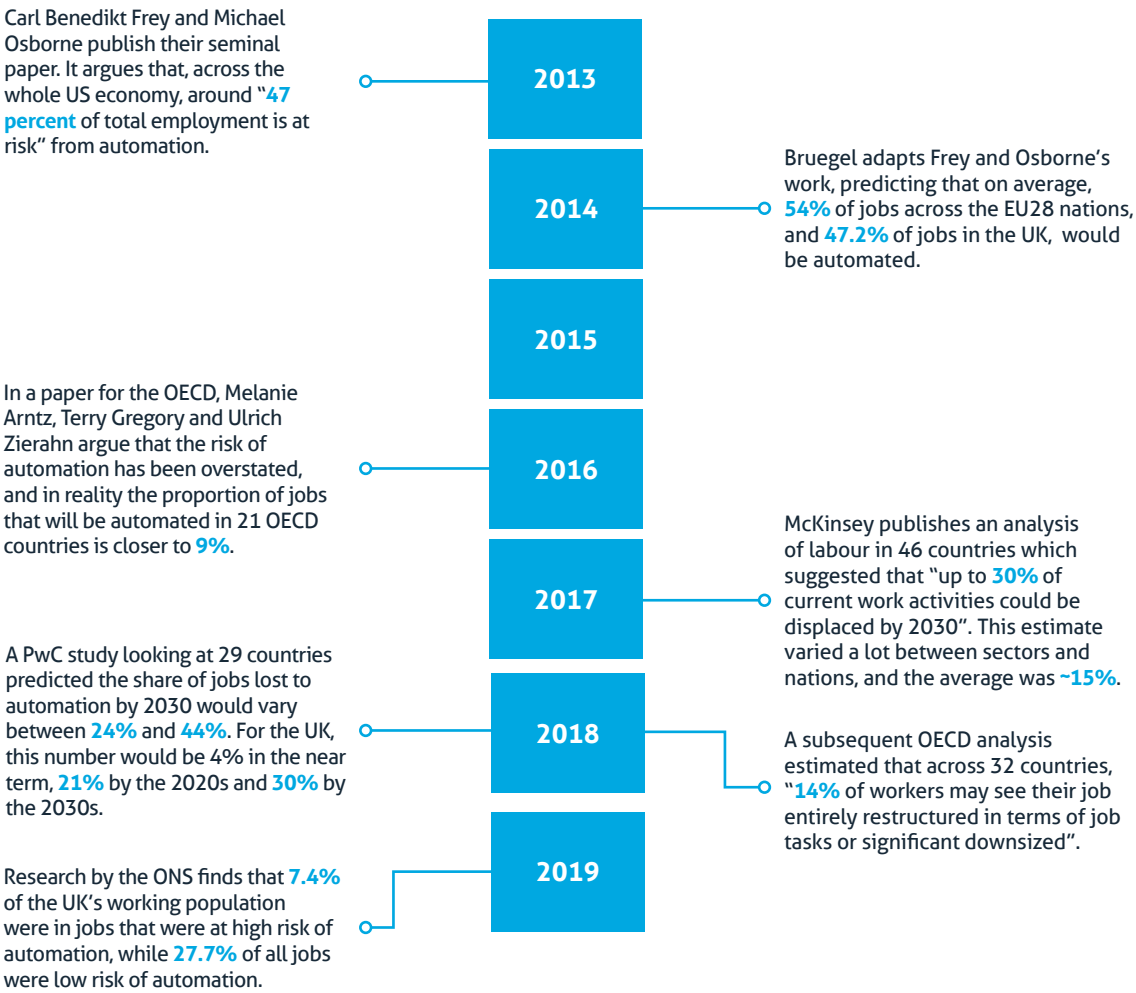
Source: Institute for Government analysis.

Automation will transform or eliminate many jobs across the wider economy

Studies on the future of work have produced a wide range of forecasts for the impact of automation. At the lower end, two OECD studies predicted that between 9% and 14% of jobs in its member countries will go within the next 10 to 20 years.[41,42] The Office for National Statistics estimated that 7.4% of workers in England were in jobs at high risk of being automated.[43] A study of UK regions predicted that inner London would see the least impact from job automation due to AI, while Cumbria would face the most – largely due to the high concentration of manufacturing jobs in the region.[44]

Other studies have predicted far more dramatic shifts. Frey and Osborne (2013) predicted that around half (47%) of jobs in the US were at high risk of 'computerisation'; the think tank Bruegel painted a similar picture for EU member states (54%).[45,46]

Figure 3 **Timeline of selected major publications producing estimates of the impact of automation on jobs**



Source: Institute for Government analysis.

These studies all predict that the impact of automation will be unevenly distributed across sectors. Some, such as sales, office and administrative support, and transportation and material moving, are higher risk.[47,48] Others, such as education, legal, community service, arts and media, and management, business and financial, are lower risk.

More recent papers tend to make more moderate forecasts: the highest estimate in the latter half of the 2010s is 44% (PwC, 2018), with most closer to 15–30%.[49] The general divergence between these shows above all the level of uncertainty surrounding the new technologies covered in this report.

2. Technology and the government workforce

Governments are the largest employer in almost every nation around the world. The UK civil service currently employs more than 420,000 people (full-time equivalent, FTE).[50] In addition to many 'white collar' roles – policy advisers, scientists, lawyers and auditors – the government workforce includes more 'hands on' roles such as prison officers, forest managers, court ushers, bailiffs and van drivers.[51] Beyond the civil service is the wider public sector, which employs more than 4.5million people (FTE),[52] and includes local government, the NHS, education and the armed forces.* Deloitte has estimated that in the UK "up to 861,000 public sector jobs ... could be automated by 2030, saving some £17 billion annually in wages compared to 2015".[,53,54]**

Technology has made whole sections of the government workforce redundant in the past. The development of word processors and printing technology spelled the death of government typing pools (just as with our lighthouse keeper example earlier). In 1989 the National Audit Office estimated that the civil service spent £300 million annually getting work typed, noting that this was "not an end in itself" and that "using technology to best advantage [was] therefore of considerable importance".[55]

But today most of the types of job that are at risk of being made redundant through technological automation, while common in the economy at large (shelf stacking or bar staff, say) are uncommon in government.[56] Conversely, many of the occupations least at risk are common in the public sector or central government, such as research and development managers, economists and statisticians, and chief executives and senior officials.[57]

Technology will instead change – or create – more roles in government than it eliminates. Government leaders will have choices about how they harness these changes. Chiefly this is a question of efficiency versus effectiveness: do they use technology to reduce the number of people employed to do high-value work, keeping output constant and reducing costs, or do they maintain the workforce and allow output to grow?

* While this report focuses on the civil service, it draws some examples from the wider public sector. Our conclusions about how new technologies will change work will have broad relevance to any public sector organisation.

** This number includes teachers and doctors, otherwise not specifically covered in this report. The researchers also note that this will be a gradual process.

Automation will change more roles in government than it eliminates

Almost every role in government will be affected by new technology, but the pattern of this change will be more complex and subtle than waves of redundancy. Most roles in government involve a mix of routine and non-routine tasks. The share of work that is routine decreases as roles become more senior and become increasingly focused on management, analysis, strategy, planning and other non-routine activities. For many in government the impact of new technology will therefore be gradual or nuanced. As routine tasks are automated, employees will be able to refocus their time on other activities.

But non-routine tasks will also change. For example, managing staff involves a range of skills that machines cannot replicate (such as interpersonal skills) but new technologies will change the *way* this can be done, for example by tracking staff wellbeing and workloads, so providing managers with new information that helps them support their staff better.

But some government jobs will be automated

Some jobs will cease to exist. These will be ones concerned with tedious and repetitive tasks that machines can do quicker, more easily, and cheaper than a person.[58,59] Some government organisations, such as HMRC, quoted below in a recent annual report, are already using technology to automate tasks:

> "We are also leading the way in government in our use of robot process automation, that provides a more efficient approach to delivering services, removing manual processing tasks and freeing up our people for customer-facing work. We've deployed 78 robotic automations, that conducted 15.7 million of our transactions in 2018/19."[60]

These forms of automation can dramatically boost productivity. HMRC offers context of what this change looks like in practice. In 2017/18, it reported that it had "promoted 4,002 people, including 188 Administrative Assistants who were promoted into more rewarding and challenging positions, as automation reduces the need for so many manual and support roles".[61] And then again in 2018/19 it "promoted 5,200 people ... including more than 60 Administrative Assistants, into different types of roles, as automation reduces the need for many manual and support roles".[62]

But while this means promotions for some, automation will create redundancies. There are tens of thousands of people currently employed in call and contact centres across government who are starting to be replaced by automations – specific applications of a technology that automates a work task. Organisations including the Ministry of Justice (MoJ), Driver and Vehicle Licensing Agency (DVLA), and HM Land Registry (HMLR) are already deploying chatbots to handle customer calls in place of human operators.[63,64,65]

HMLR chatbots

HMLR handles millions of routine requests for information every year. In the 12 months to June 2019 it handled nearly 27 million applications to add, update or retrieve information.[66] Of the 20,000 daily applications to change the registration of a property, around 18,000 are "straightforward" while the remaining 2,000 are "more complex processes such as first registrations".[67] These applications are processed by HMLR's 3,000 registration experts.[68]

HMLR has set itself the goal of becoming the speediest, simplest and most open land registry in the world.[69] To achieve this, the organisation has turned to robotic process automation (RPA) to improve the efficiency of its operations. It aims to increase the number of daily transactions resolved automatically from 81% in 2016 to 95% in 2022.[70] Automation improves customer service as requests receive near-instant responses, 24 hours a day, 365 days a year, and machines can perform these tasks far more cheaply than people on a per-transaction basis.[71] HMLR argues that using RPA for simple transactions has freed up its caseworkers to "focus their time on the more complicated land registration matters that need their expertise".[72]

Many of these roles are in the lower grades of the civil service – such as administrative officer and assistant levels – and concentrated within a few departments and public bodies. They are also quite widely distributed across the UK. The four largest departments in government also have the largest proportion of their workforce in junior grades, and most of their workforce is based outside London. For instance, the Department for Work and Pensions, the largest department, had more staff based in the North West in 2018 than any other region.*

Table 1 **Size, grade structure, and location of staff within the four largest government departments**

Department	Staff (2020, FTE)	Staff at EO/AO/AA grades (2018)	Non-London staff (2018)
Department for Work & Pensions	72,290	84.01%	90.46%
Ministry of Justice	72,120	79.63%	82.39%
HM Revenue & Customs	61,010	63.39%	87.03%
Ministry of Defence	54,540	52.87%	93.72%

Source: Institute for Government analysis of Office for National Statistics, 'Public sector employment - June 2020', 15 September 2020; Office for National Statistics, 'Civil Service statistics - 2018 edition', 3 August 2018.

* The most recent data for civil service location is from August 2018.

The government will need to pay close attention to how automation is transforming its own workforce, just as much as it will need to track how automation brings changes across the wider economy. In particular, it will want to ensure that these changes support its wider 'levelling up' agenda.

Technology will augment most government jobs – not replace them

Most government workers will see technology augment their work. Machines will automate some rote tasks that are part of their role, but not other, less routine tasks. Work activities such as record management, copywriting and routine data analysis have all been changed by technology over time, with technological automations such as the spell-checker and tools built into spreadsheets. But these advances have tended to produce machines that augment the work done by people, rather than automate it. For example, calculators dramatically increased the speed and scale of what accountants could achieve by simplifying low-value elements of their work.

Similar changes are already happening. Ofsted's electronic evidence-gathering tool automatically converts handwriting or voice notes to text, making it easier for inspectors to record and share information about schools.[73,74] Similarly, the Animal and Plant Health Agency (APHA) is using robotic process automation (RPA) to automate data entry for reports produced when its inspectors visit farms.[75]

In the short term this process of augmentation will mean that government employees can refocus on other parts of their role that might be less routine, more complex, or both. For example, the Department of Health and Social Care (DHSC) established a £250 million AI Lab in 2019 dedicated to the use of AI to improve health care in the UK.[76] Its goals include finding ways to "automate routine admin tasks to free up clinicians so more time can be spent with patients" and developing predictive medicine approaches that can automatically identify patients deemed 'at risk' from certain diseases. And there are other, more subtle ways that machines will augment the work done by people.

Some augmentations will be small – the Ofsted example is useful if not transformative – but others will be far larger. More futuristic examples include robotic exoskeletons for staff working in MoD warehouses that boost the wearer's strength and speed as they move goods around.[77]

Digital kiosks in prisons

The UK government operates 109 of the 123 prisons in England and Wales, in total housing around 84,000 inmates,[78,79] and the MoJ employs around 20,000 prison officers to guard and operate these facilities.[80] Prisoners can access a range of services within prison – including purchasing snacks or other essentials, booking visits, getting information or registering for various educational or rehabilitation programmes. In the past, these were processed via paper requests submitted to officers. These had been "a major source of frustration for both offenders and officers as [they] often get lost and are time consuming".[81]

Digital kiosks have now been introduced to 11 UK prisons, through which inmates can fill in forms automatically, and their presence has freed up a substantial amount of prison officer time that they can re-dedicate to other, more important tasks.[82]

While some automations – generally the simplest – will be enabled by a single technology, the augmentation of work will often depend on multiple technologies working in combination. As AI becomes more mature its ability to automate the analysis, management and use of data will make many other technologies possible, from self-driving cars to augmented reality (AR). This will have a cascading effect on the work done by government employees, as tasks that were previously difficult or impossible to automate become straightforward.

The UK Border Force's ePassport gates

The UK Border Force operates a system of 'ePassport' gates at many entry points to the UK. These use biometrics in conjunction with smart databases and sensors to help officers screen people entering the UK – who numbered 46.2 million in 2017 alone.[83] A single officer can monitor up to 10 ePassport gates at a time. This has made it easier for Border Force staff to "focus on what we are interested in" – activities that cannot be automated as easily such as safeguarding, interacting with passengers, and performing counter-terrorism referrals.[84]

Automating cognitive tasks means changing how the government works with information

Cognitive tasks involve doing something with information. Many of these tasks are transactional and involve an exchange: collecting, receiving, generating or sharing information. Other cognitive tasks involve taking an action on information, such as analysis or a decision. This applies to routine and non-routine tasks. Transactional tasks are the most straightforward to automate, and rarely need any of the more complex of the new and emerging technologies, such as AI.

The government has already automated many of its digital public services

The government is automating the simple transactions that are central to many public services.[85] Many of these services receive information from members of the public or businesses. All driving licence renewals with the DVLA, for example, are done online, without major human involvement at any step – by early 2019, 97.8% of all interactions with the DVLA were done online.[86]

Similarly, there are services that send out information – for example, notifications for medical appointments, flood alerts, or warnings to farmers about animal disease outbreaks.[87,88,89] Others handle payments, issue licences, register births and deaths, and hundreds of other routine public services. All this work used to be done by people.

These automations do not rely on complex, intelligent technology – for example, the Home Office's online passport renewal service is built using standard web forms and cloud technology.[90] This service automates a range of data-validation and data-entry tasks that were previously done by caseworkers at HM Passport Office.

New services like these are built digitally from the outset and this means that much of the work they do is automated by default. And their development has not led to waves of redundancies. The benefits of these automations are clear: McKinsey has estimated that digitising public services halves the time it takes for a user to access a service, halves the cost to run the service, and reduces the case-handling effort by 60%.[91]

The government is automating many internal transactions

There are similar transactional services that have been developed internally – for example, the Government Digital Service (GDS) developed an app to manage work rotas.[92] But in addition to this the government is pursuing an ambitious transformation programme for its corporate shared services.[93] This was on track to deliver £400 million in savings for the government by 2023, and likely still will, despite the Covid crisis.[94] If anything, the crisis has underscored the importance of the shared services agenda and accelerated its development.[95]

These shared services include business functions common to most or all organisations in government, such as HR, finance and business intelligence. Simple process automations offer many ways for government organisations to scale up a wide range of tasks in these areas.[96] Robots now manage expense claims and generate payslips for officials when they need them.[97] Similarly, by 2018 robotic automations at HMRC had processed more than 10 million transactions.[98]

Enterprise resource planning (ERP) platforms offer ways to automate many cognitive work tasks that used to require an employee. These range from automatic payroll software to chatbots that handle leave requests; tasks that previously took up a lot of time for finance and HR professionals within. The MoJ now uses a robot to automatically handle requests for parental leave. As a department it gets around 150 of these a month and each one takes an HR manager around 15 minutes to process; this is cut down to 3 minutes by using the robot. The time savings mean that "employees' time can be better spent on the difference we can make for citizens, rather than working on admin tasks".[99]

The Department for Education is using RPA to manage the communications it receives

Like most government organisations, DfE has to manage a vast amount of correspondence. It receives around 120,000 messages from the public every year, including questions, comments and complaints.[100] To sift and manage these it partnered with Capgemini to develop an RPA system called ARNOLD (automated robot negating the onerous logging of data), which uses a set of rules to classify incoming messages.[101] This has entirely replaced all the manual data entry tasks associated with the emails and letters that DfE receives.[102] The work done by ARNOLD allows the communications team at DfE to shift the focus of their work from admin to delivery. It has been easier for them to adapt to the new and changing ways in which the public contacts the department, such as by live chat and social media. ARNOLD also materially improves the work of the people within DfE who have to act on the content of communications. For example, its speed and scale means that messages about at-risk children or extremism are picked up faster and can be acted on sooner.

Technologies will streamline the way regulators and others collect and store information

The government gathers and disseminates many more forms of information than provided through its transactional public services. Regulators and other agencies continually collect information to guide the development of policy and how they operate. At the heart of this activity are a set of cognitive tasks that are still often done by government employees. Here, too, automation is already having an effect.

Satellite imagery has been used to map terrain, track the levels of oil in fuel tanks, and monitor other assets.[103] In 2019 the mayor of London, Sadiq Khan, backed a project that uses air-quality sensors to generate a real-time map of air pollution in London.[104]

Blockchain at the Food Standards Agency

The Food Standards Agency (FSA) is a non-ministerial government department that works to protect public health by ensuring that food is safe.[105] Its role includes oversight and regulation of food supply chains in the UK. Incidents such as the horsemeat scandal in 2013 highlighted the challenges of combating 'food fraud' and ensuring that all produce is fully traceable.[106] To protect consumers in the UK, the FSA ran a pilot scheme to test the use of blockchain* to record information about the movement of cattle from field to slaughterhouse to store.[107] It created a secure, easily audited database of livestock movements, down to the level of individual animals,[108] simplifying auditing and inspections, and improving transparency and traceability in the food supply chain.[109]

* A blockchain is a form of distributed ledger that stores information, such as transaction information, as a 'block', adding them to the database by linking that block to the 'chain' of existing blocks using a cryptographic signature. These records are shared across many computers rather than being held centrally, and changes – such as adding a block – are immediately reflected across the network.

Analytical work will also be affected by automation

After transactional tasks the next type of work that will see automation are tasks that form part of analytical roles. These are tasks that involve doing something with information that is more than just exchanging it. Analysis is a broad category and includes a lot of non-routine work that will not be immediately amenable to automation. But there are also many tasks, currently done by government employees, that are now in the process of technological transformation, or soon will be.

This is the first time that many of these roles will be experiencing any form of automation. These tasks are central to thousands of roles across government. The changes that will follow represent the most significant shift in how the government works in decades and need to be taken seriously.

Automating data validation is the first step towards automating analysis and decision making

Validating the data involved in transactions is one of the simplest forms of analysis. It involves checking that the information received matches what was expected or needed. Data validation is an important activity that ensures that the information government uses to make decisions or inform policy is both complete and error-free.[110] This type of task currently relies on a lot of human labour, but it is increasingly being automated and heralds the next phase of technological transformation.

Using machines to make decisions will be a complex step; for some types of decision this will be controversial, for others it will be impractical. But while there are some decisions that have almost no chance of being automated, there are many small, routine decisions that will be. These might range from routine approvals – automated management of leave requests is one area where change is already beginning to happen – to decisions such as when or where to dispatch an inspector. Before this becomes reality though, there will be automation of the underlying systems that validate and manage many forms of routine government data.

The ONS is automating business surveys

The Office for National Statistics (ONS) gathers data about businesses in the UK. One way it does this is via a series of around 80 business surveys. These used to be published by the ONS and sent out to companies in hard copy to be returned via post. The whole process has now been digitised and automated and doing so "saves time and resources for the ONS, as well as reducing the burden for our users".[111]

Automating routine forms of analysis will make officials more effective

AI is already used as a research tool, but it will become more integrated into the day-to-day analytical work that officials do within government. Some of this augmentation will be invisible. In the same way that tools such as spell-checkers seamlessly augment the way people write, many of these tools will become a natural part of how

government employees work with all forms of data. Others will enable new tools that help officials automate routine parts of their data work – such as building datasets, manipulating them, and preparing them for analysis.

The Department for Business, Energy and Industrial Strategy (BEIS) is using AI to understand energy data

BEIS is responsible for ensuring that the UK has a "reliable, low cost and clean energy system".[112] To support this goal, the department collects a wide range of statistics about energy prices, efficiency, sub-national consumption, fuel poverty and the wider energy sector.[113] These are published in an annual report known as the *Digest of UK Energy Statistics (DUKES)*.[114]

Assembling this information is time consuming and labour intensive, requiring a dedicated team within the BEIS analysis directorate. These analysts collate information from a wide range of sources, including digests, fuel reports and other statistical bulletins; the information is currently stored in a series of linked spreadsheets.

In a typical month, the team of analysts spends around 75% of their time assembling and validating information, but only 25% of their time actually analysing it – BEIS hopes to use new technology to reverse that. Algorithms and other forms of AI will be used to automatically gather statistics from a wide range of sources. These will be stored in 'smart databases' (rather than spreadsheets), making them easier to analyse, allowing staff to delve deeper and offer better insights.

As such, this type of technological augmentation is not being used to drive efficiency savings; rather it is being used as a way to boost the overall effectiveness of government, by maximising the value of the labour of civil servants.

Automation will change the way government employees create forecasts

Using information to make predictions and forecasts is a type of analytical work that is common within government. It ranges from anticipating trends in demand for public services, to the outcomes of a new policy, to long-term horizon-scanning efforts that seek to identify threats and opportunities that the government should be aware of. New technologies are being used to automatically produce forecasts quicker, more accurately.

AI at the MoD and the Met Office

The MoD is funding the development of a 'predictive cognitive control system' that uses 'deep learning'-based neural networks to make sense of complex information about threats and resources. A neural network is a computer system inspired by the networks of neurons in animal brains which can analyse data, identifying patterns and learning from them. This system offers military commanders and civilian decision makers confidence-based predictions about future events and outcomes.[115]

The Met Office makes widespread use of neural networks to support its forecasts. These methods help to predict a wide range of weather features such as rainfall, visibility and the height of the cloud ceiling.[116,117]

Technology will transform how governments understand issues and make policy

Just as some new technologies are creating new ways to gather, collate and analyse data, others are making it easier to explore and interact with the data itself. Virtual reality (VR) has a range of potential applications, from education to policy making. Similarly, simulations can help workers envision – and thus better understand – possible future scenarios.

Simulations at the Geospatial Commission

The Geospatial Commission is an expert committee that sets the UK government's strategy for the use of geospatial data – that is, data about location.* It has identified eight major categories of new and emerging technology that are relevant to its work, including simulation and immersive technologies.[118] One way it is using simulation is to improve maps.

Maps have traditionally been static representations of an area, but with VR can be transformed into dynamic 3D models.[119] These are underpinned by rich and complex datasets and powerful algorithms that allow policy makers to interact with a simulated map and experiment with possible policy changes – such as what the effects of relocating a bus station might be for the transport system in a town or city. Other applications include using simulations to model flood risk and maintenance demand for government organisations.

* The Geospatial Commission comprises six core partner bodies – the geosix: HM Land Registry, Ordnance Survey, UK Hydrographic Office, the British Geological Survey, the Coal Authority, the Valuation Office Agency. For more information see 'Data Bites #13', Institute for Government, September 2020, www.instituteforgovernment.org.uk/events/data-bites-13

Technology will open up areas of work that were previously limited by resources

Machines can perform more of a given task, often more efficiently, than human employees. Machines do tasks quicker, and it is far more straightforward (and potentially cheaper) for a government organisation to purchase more technological resources to perform a given task than to hire additional human resources. There are many activities that the government does not do, or does only partially, owing to resource constraints. For example, the UK government's 8,000 organisations had a combined expenditure of around £851 billion in 2017/18.[120] The National Audit Office does not have enough staff to directly audit all of the millions of individual transactions made annually – rather, it uses sampling methods that provide sufficient, if not perfect, insights.[121] AI and other smart technologies will change this, making it possible to directly scrutinise every single transaction. This will not eliminate the need for auditors but it will shift the focus of their work from directly examining individual transactions to developing deeper insights about how the government uses its resources.

Automated analysis of large datasets will improve government's understanding of the world and its ability to act

Many of the issues that government routinely grapples with are complex, and the datasets that describe them are vast – often too large to be analysed directly by government employees.[122]

These large datasets will come in many forms. There will be numerical datasets, such as public accounts, or statistics. Government currently uses these to inform policy making and implement policies effectively. But there are many other types of dataset that machines will be better able to work with than humans, owing to scale or complexity. These include datasets that analyse:

- texts, such as reports, contracts or emails. This has applications ranging from the automation of legal discovery work, to the analysis of government consultations
- media such as images, audio or video recordings. This has applications ranging from the work that national security and law enforcement officers do to identify dangerous individuals, to monitoring the integrity of physical infrastructure
- real-time data streams such as social media feeds, environmental sensors or GPS data about vehicles.

The new ability to analyse datasets will produce new insights. For example, the Behavioural Insights Team (BIT) trialled the use of machine learning and other data science methods to analyse case notes produced by social workers. Previously, there was no easy way to analyse these – case notes are unstructured and difficult to compare. BIT's algorithm automated this process and offered new quantitative ways to assess whether a child was at risk and needed to be taken into care.[123] The algorithm counted the frequency of particular words and phrases in case notes, identifying ones that were associated with particular risk factors. It then joined this analysis of the text

with other information about the child, such as their age and gender, and whether they had been excluded from school. The final product was a risk score that a care worker could use to identify at-risk children faster and more easily.

The MoJ is using neural networks to interpret prison reports

Neural networks are a form of machine learning that underpin many of the more recent advances in AI. As a technology, it doesn't do anything specific by itself but has a wide range of potential applications that do, such as recognising patterns in text,[124] speech,[125] faces,[126] and objects in the environment around an autonomous vehicle.[127]

The MoJ is using neural networks to analyse prison reports through natural language processing. Natural language processing draws on linguistics, computer science and other disciplines to develop methods that make it possible for computers to understand language in the way humans speak or write. This application automatically combines information from hundreds of reports and makes the data searchable. This makes it easier for officials and officers to find information and identify trends.

For example, analysis of these reports is being used to study inmate conflict, to understand where violence occurs, who perpetrates it, and whether there are common causes of violence.[128] These insights can then be used to develop new processes that will aim to minimise the risks of violence.

The ability of machines to analyse larger and more complex datasets may encourage governments to try to gather new and more comprehensive information about the world. This has potential upsides, such as giving policy makers a more detailed, timely and accurate view of the issues they are trying to manage. But there are also well-known risks that arise when government, or any powerful organisation, accumulates ever more information about people and their behaviours. This includes risks to privacy, and the wider risk that a focus on 'measurable' information implicitly devalues types of understanding – so important to policy development – that come from other, less quantitative sources and methods. The government will need to keep a perspective on this as automation further transforms the way government gathers data.

The ONS is already using technology to do this as part of its 'Faster Economic Indicators' project. This aims to work with large economic and administrative datasets as close to real time as possible and build automated tools that can analyse this information to generate useful indicators. For example, networks of sensors measure road traffic in real time. Information about the amount and composition of this traffic is used as a proxy measure of economic activity – road freight in particular. Around 78% of all domestic goods are moved by road, so fluctuations in the number of lorries on the roads is one indicator of economic activity.[129]

By itself this data doesn't tell us much, but when combined with other rapid indicators it will hopefully "provide insight into economic activity, at a level of timeliness and granularity not currently possible with official economic statistics".[130]

Machines can fill gaps in analysis that were previously limited by resources and capability. As their use becomes more widespread it will become increasingly feasible to understand the impact of policies at an ever more fine-grained level. One established example of this is the government's longitudinal educational outcomes database. This resource is a collaborative effort between DfE, HMRC, DWP, and the devolved administrations in Scotland and Wales.[131] It tracks the educational performance of students in the UK from when they start school to when they join the workforce. Analysis of this information has made it possible to better understand how members of the public progress from education into work.

This technology will allow staff to refocus from data handling work to other tasks. For example, the Education and Skills Funding Agency (ESFA) is employing data scientists to develop new automated analytical tools to support policy making and design, based on a set of "interactive predictive analytical tools for the agency to predict financial and academic performance (risk and profile assessment tools, geo-spatial impact models and intervention policy modelling)".[132] ESFA has said that this has "freed up staff to undertake other analytical and operational tasks".[133]

Using technology to fill resource gaps will take pressure off key workers

Social care – a long-standing issue in government and, more recently, on the front line of the coronavirus pandemic response – is one area where the government resources constrain the total amount of work that can be done. As a result, and in the absence of home visits, many disabled or elderly people have to receive routine treatment in care homes and hospitals rather than their own residence.

Here there is a resource gap that technology can fill. Sensors and other smart devices can potentially make homes easier to live in, reducing the need for some forms of care. But they also make it possible to automate some of the precautionary aspects of care, for example, monitoring patients' health remotely. This already exists with devices like fall detectors and sensors in beds and chairs, but new technologies will take this further.[134] For example, using digital assistants to remind people when they need to take medications.[135] These technologies should mean that organisations can deliver social care in a more responsive way.

The NHS is using 'Internet of Things' (IoT) sensors to support in-home care of patients

The NHS is currently running trials of connected sensors in the homes of patients with dementia, with the goal of using the information to better monitor patients' health and provide quicker responses to emergencies.[136] These sensors can track things like the movement of a patient, whether they fall, where they are in the home, and whether they are taking risky actions. They can also integrate with other new technologies, such as digital assistants, to provide responsive advice and support to patients – for example, reminding them to take medications at the right time. This type of system creates new value, since the NHS does not have the resources to provide full-time one-to-one care for all its patients.

Technology makes it easier for the government to be more targeted and responsive

Technology is changing how the government uses information to target its work. At present, the landscape that officials for any given policy or operational area have to consider is often huge – for example, every hospital ward, every restaurant, or every vehicle owned by the military. This work is resource-intensive as officials spend more of their time identifying where issues might arise rather than solving the issues themselves. Technology allows for much better targeting of resources, leading to better outcomes for policy making, regulation, public service delivery and other government activities while freeing up staff time for other tasks.

Agencies are using AI to target inspections of restaurants and MoT testing sites

There are around 23,000 licensed MoT testing sites in the UK that conduct around 40 million MoT tests each year. These sites are inspected every one to three years and the Driver and Vehicle Standards Agency (DVSA) currently employs around 300 people to do this. The current inspection model is "resource intensive and did not allow for targeted inspections".[137] The DVSA developed a clustering algorithm that analysed data about garages, such as how often they had been disciplined for failing to apply adequate MoT standards, to create a risk score for every garage. This was then used to target resources for inspections, reducing the preparation time for enforcement visits by 50%.[138] This has also improved the enforcement of standards.

Similarly, food standards are ensured through the routine inspection of restaurant premises. However, there is only a limited number of restaurant inspectors, so the agencies responsible for this have an interest in effectively targeting the restaurants most likely to be a risk.

Machine learning and AI can help target inspections. Various approaches have been developed that use publicly available data from social media, review websites and other sources on the internet to track information, such as reports of food poisoning.[139] Trials of these approaches in Las Vegas,

New York and Chicago showed some improvement over selecting restaurants for inspection at random.[140,141]

The findings are then sense-checked by experienced people, often the inspectors who may then have to physically inspect the premises.[142] Here, technologies augment work by shifting the focus from one type of work (identifying restaurants to inspect) to higher-value work (actually inspecting restaurants).

The Ministry of Defence (MoD) is using the 'Internet of Things' (IoT) to do smarter vehicle maintenance

Maintaining the huge fleet of vehicles that belongs to the UK armed forces is a major task. The MoD wants to reduce the amount of time vehicles are unavailable, either because of mechanical failures or because they are decommissioned for routine mechanical inspection. To do this, it is looking into the use of IoT devices, such as sensors and processors that would gather and share real-time information about the condition of components and systems within military equipment.[143] This data would then be analysed by other smart systems to monitor vehicles for obvious signs of failure, and to predict when routine maintenance was needed.[144]

Humans will still perform most of the mechanical repairs themselves, but this technology would save time spent diagnosing problems, thus making the system more efficient. It would also reduce the risk of unforeseen critical failures, helping military assets to stay in service for longer and reducing the amount of labour needed to repair those.

Technology will change the relationship between work and place

There are many tasks within government that require an employee to be in a specific place at a specific time. During the coronavirus pandemic most government workers shifted to home working, a move made possible entirely by technology. While parliament sat during the 1918 influenza pandemic, for example, during the first lockdown of the coronavirus crisis the business of the House was conducted almost entirely virtually.[145,146] Currently, most government employees are using cloud services and video tools to do their work remotely.

There are other professions within government for whom travel is unavoidable, such as engineers, inspectors, surveyors and researchers. But technology will help here, too. New forms of sensors, and other technologies like augmented or virtual reality, make it possible for government workers to remotely gather the information they need to make decisions or take actions. This removes the need to travel as much or at all, releasing a huge amount of time that they can re-dedicate to other areas of their work.

The Geospatial Commission is using augmented reality to enable remote engineering

Immersive technologies are closely related to simulation – the two are often used in concert. They have some unique applications of their own. One that the Geospatial Commission is exploring is the use of AR and VR to enable experts to work remotely.[147] Drones or other people already on site would use cameras and other sensors to feed real-time footage and information to an engineer working remotely. This would enable an engineer to inspect a construction site or a piece of equipment or infrastructure that needs maintenance from their office rather than having to physically travel to it.

Automation will change more 'active' work too

It is not just office jobs that will experience change. There are many other tasks within government that are not obviously transactional or clerical in nature, but which will also be automated. The government currently employs thousands of guards and inspectors to jobs like patrolling the perimeter of military installations or inspecting environmental sites.[148] On the surface these two tasks seem quite different, but at their heart they both involve gathering information.

The officer working for the MoD guard service spends a lot of time being present in a location in case an incident occurs. Their ability to intervene is the sort of non-routine activity that will be hard to automate. However, the proactive patrolling or monitoring of locations could be automated. Sensors, drones and other technology can gather much or all of this information. This wouldn't remove the need for the guards, but it might mean that they can be used in a more targeted way.

The Environment Agency is using drones to monitor land use

Following the heatwave in 2018 the East Anglia fens were experiencing severe water stress. To manage this issue better the Environment Agency started using drones to track illegal water abstractions in the fens and elsewhere, the cause of the water stress.[149] Now it is also using drones, alongside satellite imagery, to identify areas of land that are at high risk from soil water run-off.[150] These drones require human operators, but they enhanced their work by making it easier to cover a significantly larger area in much less time.

Technology will make working in government safer

Some government employees have to undertake dangerous tasks as part of their jobs. Machines in some cases are already handling these tasks, and this will only become more common. They are already being deployed to high-risk environments such as war zones, sites of disease outbreaks, building fires and crime scenes.[151]

Machines may also be fundamentally better at resolving the types of issue found in these environments. Their technical abilities – for example, by being able to fly – make them better suited to navigating hazards. They can also gather more and better data than a human worker – for example, by using advanced sensors to construct 3D maps of a location. Given that government can remove the physical risk of deploying human workers, the result offers multiple benefits.

Defence Science and Technology Laboratory (DSTL) is developing robots to inspect hazard scenes

The UK government's Defence Science and Technology Laboratory (DSTL) sought designs for robots and drones that could be used to assess incident scenes involving hazardous biological or chemical materials.[152] This project, named 'MINERVA', was co-funded by the MoD and Home Office and led to prototypes that were tested in 2018.[153] These advanced robots can perform tasks such as generating 2D and 3D maps of dangerous areas and detecting the presence of certain gases or other chemical agents.[154] Using drones or robots to crawl or fly around hazardous sites allows specialist workers to assess locations without directly putting themselves and others at risk.

Technologies will also indirectly remove government and public sector staff from dangerous environments. Governments currently employ many people to gather all sorts of information about the world. From undercover agents to aid workers, this often involves going into dangerous locations. Increasingly, applications of various technologies will make it easier to collect information that the government needs to make decisions and form policies without anybody having to place themselves in jeopardy.

The Department for International Development (DfID) used AI to monitor conflict zones

Data about the structure and distribution of populations in developing nations is often patchy or non-existent. But this type of information helped DfID to be more effective in the support it provided. The department partnered with a UN agency and academics at the University of Southampton and Columbia University in the US to develop a machine-learning algorithm that can analyse satellite imagery to identify features such as settlement boundaries, buildings, lighting and waterways. The algorithm uses this information to estimate population densities.[155]

Here, automation makes it possible to perform remote analysis of conflict zones. The insights gained have been used in at least four countries in sub-Saharan Africa to support operational work including planning vaccine campaigns and helping these countries to safely gather population estimates for conflict regions.[156]

This technology changed how analysts at DfID worked. It not only eliminated the need to travel to dangerous regions, it also produced fundamentally better data. This made it easier for officials at DfID to perform other, arguably more valuable parts of their work, such as planning and forming strategies.

Over time, decision making tasks will also be automated

As technologies develop further, in particular AI, their potential to automate decision making will grow. Even now we are starting to use automation to generate insights that can inform decisions, but this differs from actually automating the decision itself.

There are many types of decision made within every organisation in government every day. These range from trivial choices, such as which room to hold a meeting in, to ones that will have a substantial impact on an individual's wellbeing, such as whether they are eligible for a certain benefit. At the highest level these choices extend to policy decisions that have consequences for many thousands or millions of people.

As with all tasks, decisions can be more or less routine. Some, such as the choice of whether to approve expenses or a leave request, are already being automated. Others will likely never be automated – in particular, choices that are either infrequent, impactful, or both, such as agreeing the parameters of a trade deal or deciding to close a hospital. These are choices where the absence of human accountability would be untenable.

But between those two poles there is a broad spectrum of decisions that machines may increasingly make on our behalf. These might include choices such as whether someone is eligible for a benefit, or whether a prisoner should be paroled. Algorithms and other smart technologies are already being used to this end:

- Ofqual attempted to use an algorithm to allocate exam grades during the coronavirus pandemic, with poor – and controversial – results.[157]

- The Ministry of Housing, Communities and Local Government has an algorithm that determines housing needs in different regions, and aims to allocate new-build housing targets accordingly.[158,159] The decision to revise the planning formula, in particular using an algorithm to do so, has drawn scrutiny from MPs and criticism from a wide range of bodies.[160]

- In its 2019 annual report, the Education and Skills Funding Agency reported that it had developed 26 "new analysis tools built to either automate or support operational decision making". These were being used to "enable effective decision making, influence policy making and design, and free up staff to undertake other analytical and operational tasks".[161]

Fundamentally, the impacts of automated decision making on the government workforce will likely mirror the impacts that follow the automation of other forms of cognitive work, such as data entry and analysis, or routine communications. The key difference is that many decision making tasks have explicit issues of responsibility and accountability associated with them. These responsibilities are difficult or impossible to transfer from a human to a machine.

It may be that machines present options and forecast outcomes to help officials make decisions – another form of task augmentation. It may be that, as we develop a better understanding of these technologies and how to manage them, the implementation of technologies that make decisions becomes less problematic.

3. New technologies will create jobs in government

The scope of a modern government's work is incredibly broad, far wider than that of any private firm. It is also fluid: over time government has gained some functions and lost others. The UK government has at times owned and operated commercial banks, car manufacturers and utility companies.[162,163,164] It relinquished trade negotiation as a function on joining the European Union; it took that role back in January 2020.[165,166] Health care or benefits have not always been provided by government, but are now seen as inherent, even fundamental, responsibilities.[167]

For much of what they do governments are the sole provider, or the provider of last resort. There are areas of work, such as dispensing justice, that government cannot stop doing, no matter how complex or costly the function is.

New technologies are already transforming both the way government works and the work that it does. In doing so, they are reshaping the workforce – reducing the needs for some capabilities while creating whole new categories of work and the corresponding demand for new skilled employees.

Technology will create new demand for regulation and regulators

New technologies are creating a range of new challenges that warrant some degree of governmental oversight, guidance or control. The government is already working to develop appropriate regimes to ensure the safe use of new technologies such as autonomous vehicles, drones, and novel types of financial instrument such as cryptoassets.[168,169,170]

Developing these regulations requires new capabilities alongside existing ones. Some government organisations will have to grow in order to deliver this capacity; and in some cases whole new organisations will be created. For example, the UK government has established the Centre for Connected and Autonomous Vehicles to "support the market for connected and autonomous vehicles".[171] Other similar bodies are likely to follow – and they will need workers.

Technology is driving the Civil Aviation Authority (CAA) to transform as a regulator

The aviation sector is experiencing rapid and radical change in response to new technologies.* Developments in technologies such as automated air traffic management (ATM) systems and unmanned aerial vehicles (UAVs), including drones, have driven demand for new types of regulation and advice. This has contributed to the recent expansion of the CAA as an organisation – its workforce grew by around 20% between 2016 and 2019.[172,173,174]

The work of air traffic controllers is also changing.** Tasks such as processing radar information, managing arrival and departure information, predicting the trajectories of aircraft and detecting potential conflicts between flight paths are increasingly being automated, using technologies such as AI.[175,176] The CAA is responsible for ensuring these technological changes do not compromise air safety, and the regulator has had to develop new capabilities to meet this demand.

To take a recent example, the CAA wants to promote the safe use of drones and other UAVs for recreational and commercial use;[177,178] however, it must also recognise the growing demand for policy and regulation to address the harmful or illegal use of UAVs, such as disrupting airports or facilitating crime. This has pushed the CAA to develop novel research and regulatory capacity that can answer these and other questions.

Technology will create new demand for roles that guide and govern its use

The government will also need to hire more people to work on issues such as data management, cybersecurity, risk governance and ethics.[179] Governments need people with these skills to directly improve their own ways of working. They will also help to draft guidance and standards that support the safe and appropriate use of new technology across the wider economy. The UK government has already established new bodies such as the Office for AI and the Centre for Data Ethics and Innovation.[180] These new bodies, and their workforces, will grow alongside the demand for new technology in government, and may be supplemented by other, similar bodies in time.[181]

* In the UK this sector is regulated by the Civil Aviation Authority (CAA), a statutory corporation overseen by the Department for Transport.

** Air traffic controllers are not government employees in the UK, but they are in other countries. For instance, the US Federal Aviation Authority employs around 14,000 people to do this.

The government is currently building a new set of institutions to help it manage AI

In the past three years the government has established three key institutions: the Office for AI, the Centre for Data Ethics and Innovation (CDEI), and the AI Council. Along with the Alan Turing Institute (founded in 2015) they form the organisations at the core of the UK's AI strategy.[182] Their missions are aimed at helping the UK develop more expertise in AI, promote innovation, and further the safe and ethical use of AI and other technologies within government and across the UK more widely. This represents a novel expansion of technological capacity within government, one that requires new types of capability. And their role looks set to grow, with the CDEI poised to take on new responsibilities providing regulatory assurance for AI.[183,184]

The management of new technology requires new approaches to old problems, which can be developed only by blending new skills with existing institutional knowledge: for example, the government's new draft guidelines for AI procurement in the public sector, and the Crown Commercial Service's AI framework.[185,186]

But the transformation goes much further. Organisations across government are building up their capability in AI to help them develop the policy and guidance that government needs.[187] These include organisations such as the UK Statistics Authority, DHSC and NHSX, the National Cyber Security Centre, and the Defence Science and Technology Laboratory. Over time, the types of capability that are growing in these organisations will similarly grow across all organisations of government, as the use of AI and other new technologies becomes more widespread.

4. Technology and civil service reform

Civil service reform is high up on the Johnson government's agenda.[188] While digital capability has improved in recent years, senior ministers and advisers – most notably Dominic Cummings, the prime minister's influential former chief aide – have criticised what is seen as a lack of advanced technical skills and methods in government.[189] The adoption of new technology as a means for government departments and other bodies to be more effective and boost productivity both within government and across the wider economy has been routinely touted.[190] In a speech in June 2020 on the privilege of public service, Cabinet Office minister Michael Gove referred to the impact of technology on work:

> "The changes to the workplace the Fourth Industrial Revolution is likely to bring will see many current jobs and occupations either disappear or alter dramatically. The division between the fortunate and the forgotten could deepen perilously." [191]

Managing this transition must be a priority for government and doing so presents it with the chance to embrace technological change to help it work better. But it will not be easy: departments and other government organisations will need to actively assess their existing capabilities, the areas of their work most affected, and the specific capabilities that they will need in the future. Few, if any, are currently prepared to do this – and this presents a stumbling block for any technology-led reforms.

Technology is the latest in a long history of civil service reforms

This is not the first time that government has fundamentally changed how it works.[192] The Northcote-Trevelyan (1854), Haldane (1918) and Fulton (1968) reports* all drove substantial changes to the civil service.[193,194,195] From the 1980s, outsourcing – the practice of government tendering out contracts to private firms – gained prominence as a major workforce management strategy, following Next Steps and New Public Management initiatives.[196,197,198] Whether this government's reform agenda can achieve similar results will depend on its application to the task at hand.

* The Northcote-Trevelyan report established the principle that hiring or appointments by the Civil Service should be solely on the basis of merit. The Haldane report set out the form of relationships between ministers and officials – one of mutual interdependence. The Fulton report further developed the way that the civil service was structured, the way officials were managed, and the type of people it sought to recruit.

This will require a step-up in approach from even comparatively recent attempts. For example, while the 2012 Civil Service Reform Plan emphasised the importance of digital transformation, and how this would require the civil service to fill capability gaps, the 2016 Civil Service Workforce Plan made only a single reference to automation.[199,200] Other government documents on the topic include:

- The Government Transformation Strategy (2017), which "sets out how the government will use digital to transform the relationship between the citizen and state".[201]

- The Government Shared Services Strategy (2018, 'refreshed' in 2019), which aims to transform internal shared services, like HR and finance.[202]

- The Government Technology Innovation Strategy (2019), which "sets out how government will prepare to use emerging technologies to build better public services".[203]

However, none offers anything approaching the level of overarching technological reform envisioned in current government rhetoric. This needs to change – and the new focus on reform provides the opportunity to do so. The Cabinet Office's forthcoming workforce plan needs to offer real detail of what this will look like.

The government faces several challenges managing the next wave of technological transformation

As government organisations look to new technologies to improve how they work, they will need to confront a range of challenges.

Adopting new technology within government is not always straightforward

The UK government has a mixed record when it comes to digital transformation.[204] There have been some notable successes, such as aspects of the initial development of GOV.UK and the rapid progress of digitising public services.[205] In under five years the government went from having no digital services to more than a thousand; with more being added to meet new demands, such as those created by the coronavirus crisis.[206] However, the failures of digital government, such as Verify, the identity assurance system developed by the Government Digital Service (GDS), have been conspicuous.[207] Between 2000 and 2016 it is estimated that more than £10 billion was "spent on government IT projects that did not provide their intended benefits".[208]

Arguably the most high-profile and costly failure in recent years has been the National Programme for IT in the NHS.[209] From 2002, successive governments attempted to build a bespoke system for managing patient records and other health care services. This programme had a long history of issues, before finally being cancelled in 2016.[210,211] More recently, the Disclosure and Barring Service had to cancel its ambitious Release 1 (R1) Project after costs spiralled and successful delivery became unachievable. Despite this, ministers resisted calls to bring the development of this system in house.[212] This is a technology project that was supposed to deliver around £3 million in staffing efficiencies.[213]

The government has learned from these mistakes. The procurement of back-office IT functions is now an area of relative strength.[214] Similarly, GDS has successfully brought digital experts into government. And the Digital, Data and Technology Profession within the civil service continues to build government's digital capability by supporting effective recruitment and providing a wide range of support for career development for digital specialists within government.[215] But improvements have not been realised across the board. Within the Government Major Projects Portfolio, ICT is the category with the highest proportion of projects rated as 'unfeasible' or 'in doubt'.[216]

Government needs to decide what technologies it will 'buy in' as services and what it will build in-house

Achieving the right balance between developing in-house capability and procuring it from external organisations will be an ongoing challenge for individual organisations and government as a whole. Some new technologies serve generic business needs that are common to most or all government organisations, such as automated payroll software. Many of these technological solutions are already being delivered by private sector firms and easily tailored to the specific needs of government.[217] The recent improvements in commercial capability within the civil service, kick-started by Manzoni's skills reforms since 2012, means this transition should be relatively smooth and fruitful. For more bespoke applications, in-house capability will be needed. The UK Hydrographic Office is one organisation that has built up its in-house capabilities in artificial intelligence and data science to automate and improve how it builds maps.[218]

Organisational risks relating to technology and the workforce are often linked

Government organisations are required to detail the strategic risks they face as part of their annual reporting process. We reviewed the annual reports of 158 government organisations: 69 reported risks relating to staff while 53 reported risks relating to technology. In particular, resource shortfalls are commonly reported staff risks that arise when an organisation does not have a sufficient workforce to complete its objectives. Similarly, transformational challenges are a broader group of risks relating to the ability of organisations to respond to changing circumstances. These include risks such as the failure to update legacy systems or adopt new and relevant technology.

As government departments, public bodies and other organisations adopt new technologies they will create new demands for certain capabilities. If multiple organisations are pursuing the same type of transformation in parallel it creates a risk that a rise in demand for specialist capabilities coincides across government. This could drive up costs in both the short term, as departments compete with each other and the private sector to acquire certain capabilities, and in the long term, if adoption and implementation efforts are botched and require remedial fixes. Transformational risks are greater where government organisations have bespoke technology requirements that are served by neither the market nor other parts of government.

There is also a popular argument that robots, by adopting tedious rote tasks, will free people to pursue more creative aspects of their life and work.[219,220] However, this makes sweeping assumptions about both the nature of work that will be automated, and people's enjoyment of that work. There are many types of low-value task that may be difficult to automate; and there are also many tasks that people find interesting and enjoy doing but are nonetheless easy to automate.[221]

Staff turnover due to new technology can impose costs on government organisations

Government organisations have good reasons why they would want to minimise the amount of staff turnover caused by technological change. While we expect that, on the whole, technology will not drive mass redundancies, it will change many individual roles as well as the overall profile of the workforce over time. Hiring staff or making people redundant are both time-consuming and expensive activities. The cost of replacing an employee can be more than £30,000 – arising from a combination of the productivity lost while a position is vacant, the cost of staff time to sift CVs and interview applicants, and the reduced productivity that newly appointed employees have while they adjust to their new role.[222] Churn is already a problem for the government; the Institute for Government has previously estimated that "excessive turnover in departments costs the civil service between £36 million and £74 million each year in recruitment, training and lost productivity".[223] As noted, the fact that technology will leave no government job untouched will likely lead to further turnover.

There are other distributional costs associated with the adoption of new technologies, and the automation of work in particular. If the impacts of these changes fall hardest on the most junior roles then this could restrict pipelines of new talent which the government has worked hard to establish. Similarly, technological change that demands extensive re-skilling could disproportionately affect older workers. Specialist automations could also displace government employees with particular subject-matter expertise or institutional knowledge that would be difficult to capture or replace. Technology can create a wide range of legacy issues – where organisations depend on technology that is outdated and difficult to maintain. This then requires organisations to invest in capabilities that are otherwise unnecessary, solely for the upkeep of a particular system.[224]

Many government organisations have yet to consider the challenges and opportunities that new technologies offer

We reviewed the key business documents* for 201 government organisations. The results show that while many organisations recognise ongoing technological changes, few explicitly acknowledge automation, and fewer still explicitly link automation to changes in their workforce. Of those that do, hardly any are creating plans for how they will manage the impact that automation will have (and in some cases is having) on their workforce. None of the organisations we surveyed viewed automation as a major risk. The organisations that do discuss it generally state an explicit link between the use of automation in their work to efficiency savings via reduced headcount.

* We used the most recent annual reports and accounts for all organisations. In case of ambiguity or uncertainty we also cross-referenced our analysis against business plans, technology strategies, transformation plans, people strategies or other similar documents, where relevant.

Managing technology reforms will require action from both the centre of government and individual organisations

The impact of new technologies will be distributed widely across government and public bodies. There will be common features of this process of change, and the centre of government can help to co-ordinate these: in particular, parts of the Cabinet Office such as Government Automation and Business Services, the Government Digital Service, and Civil Service HR.

These bodies can provide information and guidance about how organisations can assess workforce and technological risks, and how they can support employees through a technological transition that affects their role. They should promote the opportunities that technologies offer. Within government, they are best placed to set standards for workforce measurement and reporting, so that government organisations can better understand their skills base, and share this information with others. These organisations and others, such as the commercial function, can also help support activities such as procurement.

But there will also be bespoke features of these technologies that will have limited relevance across government, but significant impact within individual organisations. The government bodies will need to work within this context and form plans for how they will manage the change.

Centralised organisations can provide specialist expertise and a buffer against capability shortfalls

The government cannot entirely avoid the need to employ people with new technical skills. There are some bespoke solutions that it will have to build in-house, and it will also need this expertise in order to work effectively with private sector suppliers. These skills will be in high demand, both within government and across the private sector. These skills will probably include:

- Designing and building systems that use new technologies to solve problems in government – from analysis to service delivery
- Developing and administering new regulatory regimes
- Overseeing the ethical development and use of new technologies – in particular, where they are used to make decisions.

One way of mitigating against sudden and expensive surges in demand for specific capabilities would be for the centre of government to develop a shared pool of specialist talent. This is the model similar to that offered by Government Digital Service (GDS) for digital public services. Government Automation and Business Services provides similar support for government organisations as they implement automation of many corporate functions. However, outside of these clearly defined areas there are fewer existing bodies that can provide the types of capabilities required.

Another model for this is the Canadian government's 'Free Agents' programme.[225] This system has a 'cloud' of workers who are not tied to any one organisation and can be deployed to provide specific technical expertise anywhere across the whole of government.[226] As these free agents are already government employees it makes it quicker and easier to appoint them to roles within project teams, while they also reduce the need to make a long-term commitment to an individual with specific – and potentially expensive – skills.[227]

The digital and HR functions can also help develop guidance around how to evaluate new technology, implement it and manage its general impact on the workforce

While there are many examples of technologies improving the work of government, there often remains a gulf between the promise of technology, and real applications. Many technologies, especially cognitive ones, have limits that are not always widely acknowledged by the industry or media.[228] This is an area of work where the cross-government specialisms will play a key role; in particular the digital and HR functions. These, and their corresponding professions, should be the points of co-ordination for advice about automation that will help technologists and HR professionals within government understand how to manage these technologies and their impact on the workforce.

Individual organisations will need to develop specific plans for specialist applications of technology to their particular business areas

Individual departments and government bodies cannot rely solely on the centre of government for support and guidance. While there are many applications of technology that will have common benefits across many or all government organisations, such as HR or commercial technology, there are many other niche applications that will be relevant to only a single organisation. For example, the AI tools that enable automated coastline mapping have specific utility to the UK Hydrographic Office, but almost no others in government.

Given the size and complexity of government as an organisation, all its constituent bodies will need to look closely at their own needs and form plans for how they will manage the impact of new technology on their workforce. This will follow the direction set by the centre of government tailored to the particular realities of their own organisation.

The UK government has shown that it can set and deliver high-level workforce objectives. Most recently its emphasis on diversity and inclusion, implemented at the highest level, has driven steady improvements across the civil service.[229] The representation of black, Asian and minority ethnic (BAME), and disabled individuals within the civil service has risen and is now close to or at the level of the wider working population. Just as government organisations have found ways to become more diverse and inclusive, so too will they find ways to become more technologically adept.

Recommendations

The following recommendations are a set of three actions to guide governments in the near term:

1. **The government must develop a new overarching strategy for the future of the civil service workforce.**

   The Cabinet Office and Civil Service HR need to deliver a new strategy that clearly articulates how technology supports the government's vision for the future of the civil service. This should offer a definitive guide for how government organisations should prepare for this change. It should:

   - describe how the government sees technology as a means to be more effective and more efficient, assign a specific priority it gives to each of these ambitions, and offer advice about how organisations should approach the hard choices they will face during this transition

   - outline the role that cross-government organisations such as the professions and functions will play supporting government workers through any technological transition and clarify the roles of organisations such as Government Automation and Business Services, the Government Digital Service, the Office for AI, and the Centre for Data Ethics and Innovation.

   The strategy should set out a high-level view of how technology will change the government workforce as a whole, and require departments and other government bodies to do the same for their individual teams. It should build on the ideas put forth in the Civil Service Workforce Plan 2016–2020, the Government Technology Innovation Strategy and other government strategies such as the National Data Strategy. But it needs to go further.

2. **All government organisations should develop independent and individual workforce plans that outline how they will manage specific aspects of technological change relating to their own workforce.**

   All government organisations need to have a new workforce plan in place. These plans must provide a detailed description of their current workforce and the workforce that the organisation expects it will need in the coming years, based on political priorities and existing business plans. These plans should:

   - specify how the organisation will audit their current skills base to better understand their workforce in light of technological change

- identify technologies that will change specific functions of the organisation – such as any public services that it provides, such as inspections – and consider how the adoption of these technologies will change the work done by their employees

- consider the workforce they need to achieve this, and how this compares to their existing skills base

- describe how the organisation views the balance of redeployment, retraining, redundancy and rehiring as interventions that will support workers. The understanding of these interventions should be developed in partnership with the organisation's existing employees

- describe specific technological and workforce risks specific to the organisation that arise from this transition

- assess the risk that technology poses to institutional knowledge and skills and consider the risk that adopting new technologies could create legacy skill dependencies

- consider the distributional effects of automation, and how the impacts of any change may be more pronounced for different groups within the organisation, particularly more junior staff

- describe how any technological change will affect career development programmes that the organisation provides

- outline who is responsible for making decisions about what technologies are adopted and how.

3. The functions and professions should play a bigger role in co-ordinating technological and workforce change across government.

As individual organisations take a lead on specific elements of workforce planning, the functions and professions need to take on an expanded role helping to co-ordinate the response to technological change across government. This will involve providing career support and development opportunities to government workers, especially those in roles which are common across many government organisations. The functions and professions should:

- expand their existing role as convenors and cross-government forums, to facilitate the transfer of knowledge and skills – in particular, any understanding of how technology is changing roles, how this shapes the careers and expectations of government employees, and the efficacy of different responses (such as retraining or promotion into new roles)

- help government to innovate more, and share the insights, learning and best practice that follow the innovative adoption of new technologies across government

- develop and maintain career frameworks similar to those already produced by the digital and HR functions, and the DDaT profession

- promote the adoption of, and where appropriate update, reporting standards for the government workforce that will enable organisations to better understand who works for them, their skills and experience. Government organisations should be required to report against the standards as part of their annual reports – in the same way that they report on their progress with workforce diversity and inclusion.

Conclusion

This is a moment of real opportunity. The government can use the technologies to transform itself for the better; applying them to the specific challenges of government, managing them, supporting the government workforce effectively through any transition, and ensuring that technologies are used in appropriate and ethical ways. But if they hope to realise the potential benefits, the organisations of government will need to reconfigure themselves.

This will not be easy. Some elements of this change are purely practical; there are financial and technical considerations that come with any effort to transform government. But there will also need to be substantial cultural changes across every government organisation and at every level of work.

Some jobs in government will cease to exist, but for most government employees technology will change aspects of their roles without making them redundant. New technologies will also create new jobs within government. In particular, governments will need people with the capability to design, develop and implement technologies. They will also need new capability in areas such as regulation, governance and ethics.

Government leaders need to evaluate the relative benefits of doing the same amount and quality of work for less against maintaining levels of funding and doing more and better work. This choice is a key implication for decision makers. The current wave of civil service reform emphasises both better people and better outcomes as goals. Using automation to refocus the time and energy of government workers into more fulfilling work that delivers better results would support these ambitions.

Organisational leaders with responsibility for the workforce need to develop better foresight of the coming changes. They need to adapt their plans and make better preparations for the way that new technologies will change the tasks done by their workforce. Some of this will come from existing cross-government bodies, such as the shared specialisms and networks such as Policy Lab and OneTeamGov. These will help employees at all levels of government to share skills and knowledge, which will in turn support broader efforts to continually develop skills and retrain the workforce.

Appendices

Appendix A: Glossary of key terms and new technologies

5G
The 'fifth generation' of mobile networks, yet to be launched in the UK, that will be faster and more reliable than previous networks such as 4G and 3G

Algorithm
A set of explicitly stated or learned instructions for performing a task, usually followed by a computer

Artificial intelligence (AI)
A range of approaches to developing computer systems that can perform tasks normally requiring human intelligence

Augmented reality
The addition of digital elements to a user's experience of the real world, for instance by superimposing images over objects a user can see through their phone camera

Automation
The application of machines, guided by algorithms, to tasks that would otherwise be performed by a human

Big data
Datasets that are too large and complex for traditional approaches to handling data, reflecting the increasing availability of data covering almost every aspect of life, but that can be hugely informative if analysed using contemporary data science techniques

Blockchain
A distributed ledger that groups the most recent transactions into a 'block' before adding them to the database. Each new block is linked to the 'chain' of existing blocks in a way that means a block cannot be altered without having to change every subsequent block in the chain.

Cloud
Computing resources such as data storage that can be accessed remotely and on demand over the internet, meaning users do not need to maintain their own IT infrastructure

Data science
The manipulation and analysis of data to extract information, identify patterns and make predictions, combining elements of statistics and computer science

Deep learning
A form of machine learning that uses neural networks with many layers to solve particularly complex problems. Each layer becomes sensitive to progressively more abstract patterns, so early layers may learn to identify the edges of objects in a photo, then the paws of a cat, with later layers building on these lower-level features to identify the cat itself.

Distributed ledger technology (DLT)
An approach to recording transactions (such as exchanges of money or data, or the agreement of contracts) in that the database is shared across, added to and verified by a network of users rather than being controlled centrally

Drones
Usually, aircraft without a human pilot on board that can be controlled remotely by a human or operate autonomously; also known as unmanned aerial vehicles (UAVs)

Internet of things (IoT)
The network of physical objects connected to the internet using embedded electronics, allowing them to collect data, communicate with each other and, in some cases, interact with users

Machine learning (ML)
A popular sub-discipline of AI that involves computers learning how to perform a task from examples and experience, without being explicitly programmed

Neural network
A simplified model of the human brain used in some types of machine learning, composed of layers of artificial 'neurons'. Each layer receives an input, its 'neurons' perform computations on that input and pass the results on to the next layer, and the last layer produces a final output (for example, whether the system believes an image contains a cat or not).

Predictive analytics
The analysis of data to make predictions about future events, drawing on advances in data science and machine learning. Applications are wide ranging, from forecasting the weather to identifying when and where crimes are likely to be committed ('predictive policing').

Privacy enhancing technologies (PETs)
A family of methods and technologies that improve how we protect personal data of individuals when this is provided to or used by services and applications.

Robotic process automation (RPA)
The use of software robots to automate a wide range of business functions

Virtual Reality
The use of technology to create simulated, immersive environments for users to experience. These can be general purpose, such as new worlds to explore in gaming, or adapted to specific contexts, such as simulators for training surgeons or pilots

Wearables
Wearable devices such as smart watches and fitness trackers that typically collect data on the wearer's activity, as well as providing other functionality

Appendix B: List of acronyms

AI	Artificial intelligence
ARNOLD	Automated robot negating the onerous logging of data
BEIS	Department for Business, Energy & Industrial Strategy
DCMS	Department for Digital, Culture, Media & Sport
DDaT	Digital, Data and Technology Profession
DLT	Distributed ledger technology
DWP	Department for Work & Pensions
ERP	Enterprise resource planning
GDS	Government Digital Service
HCM	Human capital management
HMRC	HM Revenue & Customs
IoT	Internet of things
LEO	Longitudinal educational outcomes
ML	Machine learning
MoD	Ministry of Defence
MoJ	Ministry of Justice
NAO	National Audit Office
ONS	Office for National Statistics
OSR	Office for Statistics Regulation
PETs	Privacy enhancing technologies
RPA	Robotic process automation
UKSA	UK Statistics Authority

Appendix C: Supplementary figures and tables

Table 2 **Countries considered by seven major analyses of the impact of automation on jobs**

Frey & Osborne	Bruegel	OECD	McKinsey	PwC	OECD	ONS
2013	**2014**	**2016**	**2017**	**2018**	**2018**	**2019**
	Austria	Austria		Austria	Austria	
	Belgium	Belgium		Belgium	Belgium	
	Bulgaria					
		Canada			Canada	
				Chile	Chile	
			China			
	Croatia					
	Cyprus			Cyprus	Cyprus	
	Czechia	Czechia		Czechia	Czechia	
	Denmark	Denmark		Denmark	Denmark	
	Estonia	Estonia			Estonia	
	Finland	Finland		Finland	Finland	
	France	France		France	France	
	Germany	Germany	Germany	Germany	Germany	
	Greece			Greece	Greece	
	Hungary					
			India			
	Ireland	Ireland		Ireland	Ireland	
				Israel	Israel	
	Italy	Italy		Italy	Italy	
		Japan	Japan	Japan	Japan	
		South Korea		South Korea	South Korea	
	Latvia					
	Lithuania			Lithuania	Lithuania	
	Luxembourg					
	Malta					
			Mexico			
	Netherlands	Netherlands		Netherlands	Netherlands	
				New Zealand	New Zealand	
		Norway		Norway	Norway	
	Poland	Poland		Poland	Poland	

Frey & Osborne	Bruegel	OECD	McKinsey	PwC	OECD	ONS
2013	**2014**	**2016**	**2017**	**2018**	**2018**	**2019**
	Romania					
				Russia	Russia	
				Singapore	Singapore	
	Slovakia	Slovakia		Slovakia	Slovakia	
	Slovenia			Slovenia	Slovenia	
	Spain	Spain		Spain	Spain	
	Sweden	Sweden		Sweden	Sweden	
				Turkey	Turkey	
	UK	UK		UK	UK	UK
USA		USA	USA	USA	USA	

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Acknowledgements

This project was undertaken in a partnership between the Institute for Government and SAP. We would like to thank Chris Francis and others at SAP for their advice and support throughout this project.

We would also like to thank many people both inside and outside government for their interest in our work. We are grateful to all the officials, academics and others who gave up time to be interviewed or provided feedback to us on our paper. All views expressed and any responsibility for errors and omissions are those of the author.

At the Institute we would also like to thank Emma Norris, Alex Thomas, Gavin Freeguard, Bronwen Maddox, Pritesh Mistry, Lewis Lloyd and Lee Wratten for their contributions to the research and writing of this paper. We also want to thank Will Driscoll, David Edwards, Melissa Ittoo, Louise Scarce and Sam Macrory for helping to produce the report.

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The Institute for Government is a registered charity in England and Wales (No.1123926) with cross-party governance. Our main funder is the Gatsby Charitable Foundation, one of the Sainsbury Family Charitable Trusts.