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A New National Purpose: The UK's Opportunity to Lead in Next-Wave Robotics

A joint report by Tony Blair and William Hague.

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Contents

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Foreword

In a series of joint reports published since 2023, we have argued that the world is undergoing the fastest technological and scientific revolution in human history. Given the profound implications for our country, affecting everything from the economy and public services to security and the UK's place in the world, we have urged all political parties to make responding to this technological revolution a New National Purpose. The challenge of responding is so urgent, the risk of falling behind other countries so great, and the opportunities so exciting, that nothing less will do.

This can be a transformative moment for our country. Growth in the UK has been too slow for years and productivity has flatlined for decades, but the government has an opportunity to turn this around. Whatever one's personal political persuasions, it is clear that Keir Starmer's victory in the general election has afforded him the political capital necessary to address the deep-rooted challenges affecting the UK's economy and public services. It is in the interests of everyone in our country that he succeeds in doing so.

Harnessing the benefits of technology will be key to achieving this. As set out in our three previous papers on innovation, artificial intelligence and engineering biology, new general-purpose technologies can turbocharge economic growth, make public services more efficient and effective, and improve people's lives. Realising the economic and social benefits of emerging technologies will require incentives for innovation, investment in enabling digital infrastructure and responsible development practices, as well as effective, proportionate regulation.

Robotics, the subject of this fourth joint paper, will also become increasingly central to the future of our country, as the technology continues to improve. Much of the impact of AI so far has been delivered digitally, through generative-AI tools such as ChatGPT. But many future advances will be delivered in the physical world, through robots that act as the arms and legs of AI. From self-driving cars and delivery drones to industry robots, AI-enabled robotics will transform the economy, public services and daily life.

There are important signs that the government recognises the essential role of technology. Ministers have commissioned an AI Opportunities Action Plan and committed to creating a new Regulatory Innovation Office; they have also set out ambitions to further expand digital technology in public services and encourage pension funds to invest more in Britain. The government is considering an AI bill too, designed to extend the country's global leadership in AI safety while setting the conditions for a flourishing research and development ecosystem. All of this could help enormously.

While we acknowledge the serious fiscal pressures facing the government, some additional state investment in technology will be necessary. As scientific advances continue to accelerate over the course of this parliament, it will soon become impossible to have a

strategy for growth, public services or defence without a strategy for technology. Investing more in emerging technologies now will pay significant long-term dividends, and help deliver growth and prosperity throughout this parliament and into the next one.

Robotics is one of the key technologies for which greater state support will be necessary. Today the UK has the least advanced robotics sector in the G7, with half the robots per worker in the automotive industry that Germany has. However, the fact that robotics increasingly intersects with AI – where the country does have strengths – gives Britain an opportunity to catch up. This report sets out how the new government can seize this opportunity and realise the transformative long-term benefits of robotics by addressing challenges across innovation, commercialisation and governance.

Tony Blair and William Hague

Executive Summary

The world is about to witness a wave of rapid advances in robotics. For decades, this field of technology has been held back, largely by difficulties in manually programming robots to respond to varied environments. However, recent advances in artificial intelligence are now unlocking new ways forward.

In the next decade and beyond it will be increasingly possible and cost-effective to roll out robots that can operate with a high degree of autonomy in industry, public services and wider society. A world in which your self-driving car takes you to work, the food you eat is harvested by robots, and your deliveries are packed by smart machines and dispatched via drone.

While much of the world's interest in AI is focused on large language models, they are only the beginning: the future development of AI will be largely centred on finding models for use in the physical world. Mustafa Suleyman, co-founder of DeepMind, has noted that robotics will act as "AI's physical manifestation", accelerating what he refers to as the "coming wave" of advances in AI and engineering biology that will utterly transform society.[1]

In simple terms, robotics is a set of technologies designed to perform physical tasks that have traditionally been carried out by human beings. This requires the integration of hardware (such as sensors and actors) and software (especially advanced machine-learning techniques). The term "embodied AI" is used to refer to robots that are endowed with the ability to perceive, learn from and dynamically interact with their environment.[2]

Tech companies, venture-capital firms and governments around the world are investing billions in general-purpose robotics that can perform a wide variety of tasks in the workplace and the home. Although experts are divided on how long it will take to develop and deploy general-purpose robots, they concur that steady progress is being made.[3]

Next-wave robotics will unlock more economic productivity, deliver efficiencies in our public services, and free up more time for each of us in our citizens' daily lives. Many countries have woken up to the fact that robotics will become increasingly critical to their place in the world, profoundly impacting their national resilience and security, their responses to demographic challenges, and the projection of their values and influence on the world stage.

The UK, meanwhile, has failed to produce a national strategy for robotics and deprioritised the technology to focus on other areas. The current government must avoid the mistakes of previous governments in misunderstanding the importance of robotics to the future of the UK. Instead, it should position the country at the forefront of this emerging wave of technology.

To achieve this, the government must take action now to help cultivate and drive the innovation required to realise the transformative longer-term opportunities of robotics – and to avoid falling behind other major countries around the world. At the same time, action should be taken to capitalise on the near-term gains of better deploying existing technologies

across the economy. This will mean leveraging the UK's strengths in AI software, while mitigating its weaknesses in robotics hardware.

This can be done through additional investment and action that explicitly addresses the structural barriers to developing and commercialising these technologies in the UK. In this paper we look at the most pressing challenges in innovation, pull-through capabilities (incentives and commercialisation channels for bringing scientific breakthroughs to market, driven by end-user needs) and governance.

Recommendations

Innovation

There has been a lack of government strategy here. Some of the financial backing for robotics research being directed through national funding agency UK Research and Innovation (UKRI) could be better spent, while the UK's robotics industry is significantly dependent on international talent for hardware and software expertise. To counter these issues, the government should:

- **Amend the Science and Technology Framework to specifically include robotics and embodied AI as a sixth critical technology.** Task an independent expert from the commercial robotics industry to deliver a Robotics Opportunities Action Plan, focusing on how to develop and deploy the software and hardware required.

- **Review government investment programmes for robotics research, reallocating some of the funding from UKRI for a new approach.** This should include:
    - additional grant funding for the Advanced Research and Invention Agency to support its Smarter Robot Bodies opportunity space
    - exploring future capital funding for a network of national robotariums
    - funding for the creation of open-source and modularised software and hardware, helping researchers and startups to develop more complex robotics in less time at a lower cost.

- **Explore the creation of new NHS data sets around the use of robots in health care.** One example would be collecting data from robot-assisted surgeries that could be used to train autonomous robotic surgeons, subject to strict safeguards around patient consent, secure storage and access.

Pull-Through Capabilities

The UK's relative lack of patient capital (long-term investment strategies) is a challenge for commercialising hardware, including robotics, while a lack of expertise and headroom holds back procurement in public services. The government should:

- **Create a £100m Robotics Investment Programme through British Patient Capital**, to provide follow-on funding to support early-stage and growth-stage robotics startups.

- **Explore the use of a targeted Contracts for Innovation programme** that helps public bodies fund robotics solutions.

- **Use advanced market commitments (AMCs) to pull through emerging capabilities in robotics;** the proposed Robotics Opportunities Action Plan could identify key potential deployments according to key public needs, then key potential purchasers could be coordinated to provide AMCs for different uses (such as bringing together NHS Trusts to set up automated labs).

Governance

Regulators need increased support and coordination, social concerns about robotics must be addressed and more can be done to support the export of UK robotics around the world. The government should:

- **Increase financial support for regulators where new uses of robotics and embodied AI are transforming sectors**, such as the Vehicle Certification Agency, Driver and Vehicle Standards Agency, Civil Aviation Authority and Heath and Safety Executive (HSE). This should include the implementation of the proposal of the Government Chief Scientific Adviser, Professor Dame Angela McLean, who suggests a robotics secondment scheme within the HSE, to act as a pilot scheme for bringing experts into regulators.

- **Address societal concerns around robotics and automation** by focusing interventions on automating dull, dirty and dangerous tasks, and start long-term planning for how a retraining fund for those whose jobs are displaced by robotics could work.

- **Expand the use of relationship managers or set up a new concierge expansion service for UK scale-ups**, to help connect robotics companies seeking to export with regulators and agencies in international markets.

While we recognise the state of public finances, the government should make additional investments in this area, which could be accomplished to some extent by reprioritising some UKRI funding. This will be crucial in positioning the UK at the forefront of this new wave of robotics advances. The alternative costs are even higher: unless the government acts now, the UK risks falling further behind in a crucial emerging sector, with all the economic, social and geopolitical costs that this would entail.

Trends in Robotics

The Technological State of Play

Robotics has a long history. The term “robots” originated in a 1920s play, and described manufactured beings that performed unpleasant manual labour. The concept has captured the public imagination for millennia, stretching from Aristotle speculating as to whether autonomous machines could one day make the abolition of slavery possible, through to contemporary science fiction.

The first true industrial robot, Unimate, was developed in 1954 and used to help lift heavy loads in General Motors factories. Since then, advances in computing and programming have enabled robots to perform increasingly complex tasks, while progress in artificial intelligence is set to unlock a new wave of advances.

Indeed, recent technological advances have resulted in AI-driven robots that can autonomously interact with and respond to the physical world – and they are increasingly cost-effective. Referred to as “embodied AI”, these robots mark a considerable departure from traditional robotics in that they can learn how to behave and adapt autonomously, instead of being programmed by coders. Such robots will be able to reliably perform complex tasks, such as self-driving a vehicle or delivering parcels in the form of drones.

The prize that many established tech companies and startups across the globe are now working towards is general-purpose robotics, whereby a robot can perform a range of complex tasks. Advances across software, training tools and hardware, well summarised recently by Eclipse VC’s Seth Winterroth, are making this increasingly possible.[4]

Advances in Software

Self-supervised learning models are enabling robots to learn directly from large amounts of unlabelled data, while foundation models are connecting computer vision and language, making it easier for AI software to better understand the physical world around it.[5] It is becoming easier for the general public to communicate with robots, with researchers making progress on new models that link vision, language and action to make robot behaviour explainable in natural language.[6] Advances in compute are unlocking more powerful AI models, as highlighted in TBI’s *State of Compute Access: How to Bridge the New Digital Divide*, while cloud-based tools are making it easier to resolve programming issues remotely.

Advances in Training Tools

New training tools are available to support AI within robotics, such as Foxglove’s visualisation platform that helps developers test and debug their training data.[7] New platforms such as Intrinsic are making it easier to integrate different types of hardware and software[8], while advances in simulation technology – and new learning methods such as Google DeepMind’s DemoStart – are making it easier to train AI models to more accurately conceptualise how objects move in the physical world.[9] This improves their ability in real-

world conditions, as shown by autonomous-vehicle developer Wayve's pioneering PRISM-1, a photorealistic scene-reconstruction model.[10]

Advances in Hardware

Robotic hardware has become faster to prototype with tools such as 3D printers, while falling costs are making the hardware more affordable. Surveys conducted by Stanford University show that the average price of robotic arms almost halved between 2017 and 2021, falling from $42,000 per arm to $22,600.[11] Similarly, the cost of light-detection-and-ranging (better known as LiDAR) sensors has fallen significantly, with Waymo (formerly the Google Self-Driving Car Project) cutting the price of its sensors from about $75,000 in 2009 to $7,500 in 2017.[12] In the meantime, batteries are also becoming cheaper and lasting longer.[13]

Technological pinch points remain, preventing the full benefits of robotics from being realised. Two of the biggest challenges are actuation and haptic sensors[14]. Novel actuators (the parts of a robot that help it move its wheels and/or arms) are required, as electric motors usually require heavy, expensive gearboxes that make robots stiff and slow, and make it harder to make them move backwards. Other experts have pointed to the need for actuators to be more modular and easily configured without customisation.[15] Advances in haptic sensors, which allow robots to better sense their surroundings through touch, are also required for tactile interactions – they could, for example, make robot-assisted surgeries more effective.[16] Meanwhile, progress in delivering more sophisticated prosthetic limbs will require advances in electromyography sensors, designed to capture the electrical signals generated during muscle activity.[17]

Regarding software, sufficient data to train models is the most considerable challenge. While text data to train large language models (LLMs) are readily available on the internet, the visual and other data required to train robots usually have to be captured by developers themselves. In the future, architectures using zero-shot learning, such as OpenAI's CLIP, can help bridge the gap between text and visual data.[18] Simulation software, while improving, remains imperfect because physics engines still do not perfectly model the real world – although there has been progress in this area, not least Google DeepMind's open-source MuJoCo engine.[1920]

Other software challenges include the need for advanced communication protocols, to make it easier for robots to transmit information.[21] Greater security safeguards are also needed to prevent robotics being exploited by bad-faith actors, and to protect the privacy and data of users. Advances in edge computing and fog computing could help by supporting localised computing near users and robotic devices, rather than cloud computing's approach of using a centralised location such as a data centre.[22]

Finally, in some circumstances, robots struggle to operate in specific environments. One way around this would be to adapt those environments to help robotics operate more effectively, a process that academics refer to as "envelopment".[23] Philosopher Luciano Floridi has highlighted the simple example of dishwashers, which are so effective because they are enveloped within a controlled environment (a closed box), compared with an ineffective humanoid robot trying to wash dishes.[24] The UK's drone superhighway project will also

deploy a form of envelopment, using a network of towers to guide drones along a defined virtual corridor in the sky without human intervention.[25]

These pinch points will take time to overcome but as they are resolved, the cost-effectiveness of automation will increase and applications will become more complex and varied. Embodied AI as a general-purpose technology is set to become increasingly central to the UK's economy, public services and everyday life.

The Robotics Race Is On

Across the world, countries and companies are rushing to overcome the pinch points we've outlined above, in order to position themselves at the forefront of developing and deploying embodied AI. Harnessing the robotics revolution promises economic security and prosperity, as well as improved military capabilities.

The United States is home to most of the Western world's leading robotics companies. Agility Robotics, Tesla and Figure are all making strides towards delivering humanoid robots for industrial and logistics purposes, while Boston Dynamics' Stretch robot is already improving the productivity of warehouses by sorting and handling packages.[2627] That said, Hans Peter Brondmo, the former lead of Google's recently terminated Everyday Robot Project, has questioned whether "Silicon Valley, with its focus on 'minimum viable products' and VCs' general aversion to investing in hardware, will be patient enough to win the global race to give AI a robot body".[28]

China has long recognised the importance of robotics, identifying the technology as critical to its Made in China 2025 strategy to transition to producing higher-value products. While China is a way off realising its self-sufficiency targets in robotics, and is still largely dependent on robotics from Japan, the Chinese government is using subsidies to try and take the lead on the next generation of this technology.[29] In 2023, China announced that it would seek to mass-produce humanoid robots by 2025, and ensure that by 2027 these robots are an important engine of domestic economic growth. While timelines for humanoids may prove unrealistic, and experts differ on whether the future of robotics and embodied AI is indeed humanoid, China's new $1.4 billion robotics fund will nevertheless expand its capabilities in the technology more generally.[30]

Other established leaders in robotics are also trying to extend their lead. South Korea recently announced its 4th Intelligent Robot Basic Plan, which will result in $2.3 billion being invested in the sector between now and 2030. The plan outlines the ambition to increase the domestic production rate of key robotics components to 80 per cent, rapidly review 51 key regulations promoting advanced robot deployment, cultivate 15,000 jobs in the industry and establish the National Robot Test Field to speed up the commercialisation of new robots.[31]

In Japan, one of six Moonshot R&D programmes reads: "Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050." This specific moonshot is backed by $220 million to be deployed over five years; the International Federation of Robotics (IFR) calculated that the Japanese government spent $930 million on robotics in 2022 alone.[32]

The European Commission has announced plans to publish an EU-wide strategy on AI-powered robotics early next year, with policies focusing on development and deployment. Germany, the leading robotics country in the bloc, launched Robotics Institute Germany in early 2024, focused on R&D and bolstering education through new courses and degrees.[33]

Countries that have not traditionally led in robotics are also taking action to position themselves at the forefront of this wave. India, for example, recently published a draft National Strategy on Robotics, centred on realising the benefits of robotics for manufacturing, agriculture, health care and national security.[34]

Australia published a National Robotics Strategy in 2024, focused on boosting R&D and commercialisation in areas of strength, as well as increasing the adoption of robotics in manufacturing and key sectors of the Australian economy, such as agriculture and mining.[35]

Each of the above countries has woken up to the fact that robotics and embodied AI will be a general-purpose technology with myriad uses across the economy, public services and everyday life, and therefore critical to their place in the world. The UK has yet to do so. There are three key reasons why this is a critical oversight, and the government must act now to position the UK as a leading country in this field.

1. Security

Like all general-purpose technologies, robotics is inherently dual-use: it has both civilian and military applications. From drones to unmanned submarines, and the ground systems recently backed by the NATO Innovation Fund, robots are increasingly pivotal to countries' national-security capabilities.[36] As outlined in a Tony Blair Institute for Global Change (TBI) report, *Reimagining Defence and Security: New Capabilities for New Challenges*, countries' ability to surge munitions production is essential for deterring aggressor countries. The integration of advanced industrial robots into defence manufacturing will be a key driver in accelerating capabilities to produce at speed and scale.

Robotics is also fast becoming a new front in the geopolitical competition between the West and China for technological leadership. There are already concerns that Beijing is using robotics for espionage purposes. The US is expected to ban the import of Chinese autonomous-vehicle software as a response, and is considering a ban on Chinese-developed drones.[37] Goldman Sachs has also predicted that the West could soon impose export restrictions on sophisticated robotics components, in order to hamper China's ability to produce humanoid robots.[38] Given the crucial role that robotics will play in maintaining critical national infrastructure, dependence on Chinese technology would be unwise.

While it is unrealistic to expect the UK to be a leading country in all aspects of robotics, securing a strong role in this global industry and its supply chains will help insulate it from the potential impact of a trade war on the supply and price of robotics. Furthermore, this would support the West in maintaining collective technological leadership in this area and project the UK's geopolitical power. The result would be downstream effects similar to those seen in countries with a key role in today's semiconductor trade.

2. Demographics

Like most developed countries, the UK has an ageing population and falling birth rates, causing significant skills shortages within the economy. Many other countries, including China, Japan and Italy, are using robotics to help plug gaps in their workforces, and studies show that countries with lower population growth have higher levels of robot density.[39] The UK's population is expected to keep ageing and birth rates to keep falling. As a result, future governments may consider increased automation as a way of meeting these labour-force gaps, either to complement or replace high levels of migrants.[40] Many of the occupations for which skilled-worker visas were granted by the UK in 2023 are associated with tasks that could be automated at scale with robotics in the long term. This includes, for example, non-patient-facing tasks for carers and nurses, plus some cooking tasks for chefs.[41]

3. Regulation

A strong domestic industry will play a vital role in helping the UK to influence global standards and ensure that regulation around how robots are developed and deployed aligns with Western values and interests.

As Hans Peter Brondmo has argued, "Giving AI a body in the real world is both an issue of national security and an enormous economic opportunity."[42] The UK should aim to be a rapid adopter of robotics, including importing from overseas, and carve out a key niche in both the national security and innovation domains of robotics production. Capitalising on the strengths of the country's existing innovation economy and those aspects where the export potential is obvious, while also plugging a number of crucial gaps, will allow the UK to position itself to secure first-mover gains in the coming wave of general-purpose robotics.

To achieve this, the government should help to cultivate and drive the innovation required to realise transformative longer-term opportunities in general-purpose robotics. At the same time it should capitalise on the near-term gains of better deploying existing robotics technologies across the economy.

Seizing the Opportunities

Long-Term Gains

Due to remaining technological pinch points, most of the benefits of robotics will not be realised during this parliament, but instead only become evident in the 2030s; this is when scientific breakthroughs will enable new robotics use cases with sizeable economic and societal benefits. Some of these scenarios are already emerging on the horizon.

Take self-driving vehicles, for example. In the UK, up to 40 per cent of new car sales could have self-driving capabilities by 2035; it is a market worth up to £42 billion a year, with the potential to create 38,000 more skilled jobs.[43] Thanks to autonomous-vehicle developer Wayve, which has recently announced a new partnership with Uber,[44] the UK has an edge over many other developed countries in self-driving vehicle technology, which could be leveraged as an export opportunity. Forecasts by McKinsey show that advanced driver-assistance systems and autonomous driving technology is expected to create up to $400 billion in global revenue by 2035, with most of this resulting from the most sophisticated and autonomous forms of self-driving car.[45]

Further long-term gains are possible in the form of emerging robotic technologies, with efficiency benefits for public services, particularly health care. Autonomous mobile robots will be able to act as hospital porters, moving paperwork and medicine around facilities and freeing up staff to focus on patient care, as piloted by Milton Keynes University Hospital.[46] Robots will be able to clean hospital facilities, with a robot using UV lights developed by health-care-automation firm Akara already found to cut the time taken to deep clean rooms from three hours to 20 minutes.[47] And drones will be able to deliver medical supplies; there are a number of ongoing pilots, including partnerships between the health-care logistics company Apian, Northumbria NHS Trust and Guy's and St Thomas' in London.[48]

Autonomous robotic surgery, while still experimental and beset by public scepticism, has already been found to outperform surgery performed by expert surgeons and robot-assisted approaches in some cases.[49] Automated labs will be able to process test results quicker, with a pilot in 2022 turning around an RT-LAMP Covid-19 test in one-quarter of the time taken to do a manual test.[50] Automated labs will also be able to speed up research and innovation in health care, with the platform Automata already allowing biotech research labs to increase their throughput fivefold.[51]

Robots will be able to support other critical public services too. They will become essential for the maintenance of energy infrastructure, reducing safety risks for workers; for example, a semi-autonomous crawler robot called the BladeBUG is already used on wind turbines to help inspect and repair blades.[52] Moreover, experiments by UK scientists have found that teams of autonomous robots could be used to help decommission nuclear power plants,[53] while micro-robots could one day be used to remove bacteria and microplastics from water.[54] Policing will also benefit: drones will be dispatched as first responders to crimes, helping to track suspects until police officers arrive. This is already being piloted by the National Police Chiefs' Council.[55]

Most of these use cases are unlikely to be achieved at a sufficiently low cost for mass adoption this parliament and are therefore unlikely to play a noticeable role in meeting the government's five missions. However, supporting these nascent technologies now will mean significant improvements to how the UK delivers public services in the next parliament.

A widely anticipated longer-term outcome is general-purpose humanoid robotics. Tech companies including Google, Tesla and OpenAI, and countries such as China, are investing billions in this application of the technology, which will be useful for a wide range of tasks in both industrial and domestic spheres.

While Goldman Sachs forecasts that the global market for humanoid robots will likely reach only $9 billion by 2029, it predicts that it will scale rapidly to reach $38 billion by 2035, with 1.4 million units sold every year. Moreover, these forecasts have recently been revised up, with a sixfold increase in the projected size of the market and a fourfold increase in unit sales, in response to falling hardware costs and advances in AI.[56]

Goldman Sachs' research anticipates that costs will fall further in coming years, provided the costs of key bottleneck components, such as planetary roller screws for linear actuators, come down. The forecast suggests that most units sold up until 2030 will be for industrial purposes, at which point service-sector sales will overtake, reaching 62 per cent of units sold in 2035.[57]

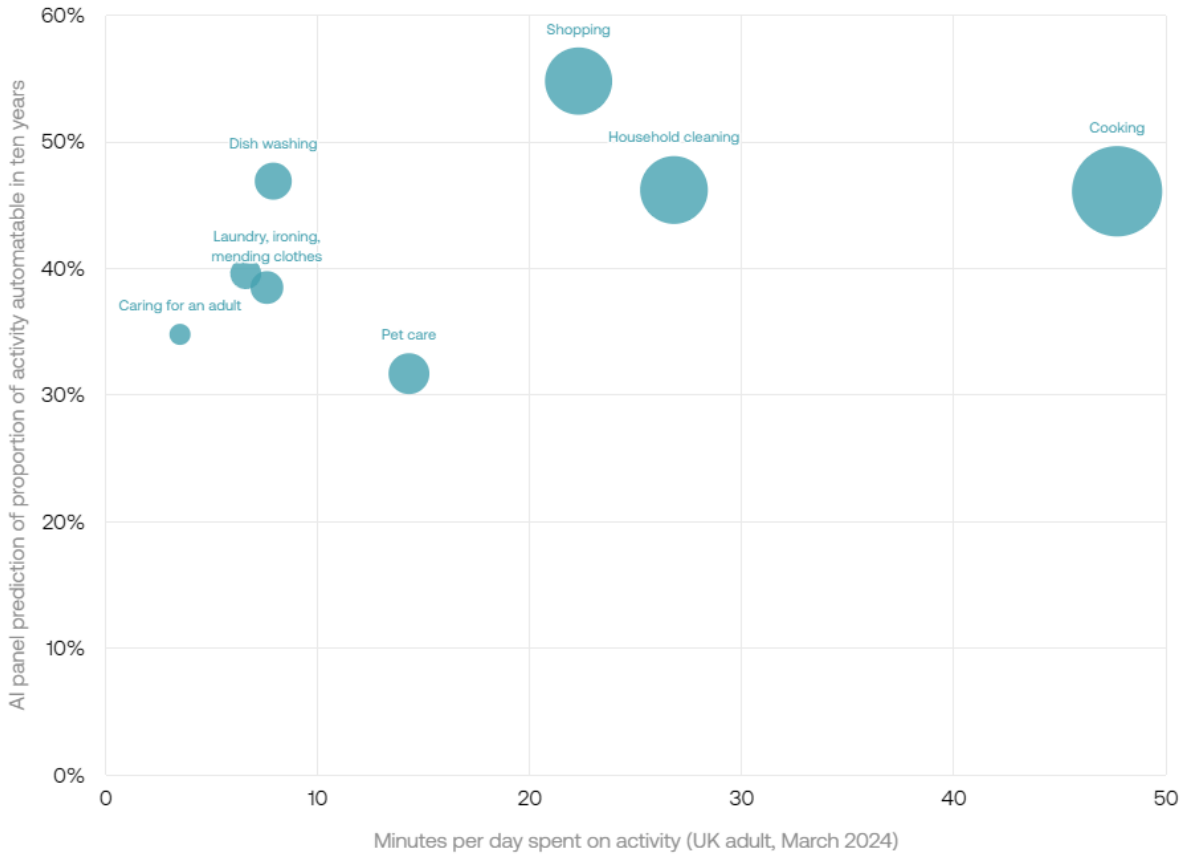
Goldman Sachs' forecasts suggest that humanoid robots will become economically viable for factories between 2024 and 2027, while service-sector applications will become economically viable between 2028 and 2031. By 2035, it forecasts that a humanoid robot will cost just $19,545, less than one-third of the cost of a factory worker's annual salary, while being considerably more productive.[58]

Across these different use cases for robotics there are considerable social benefits to be unlocked. Human error, for example, contributes to about 88 per cent of road collisions, with such collisions currently resulting in about 30,000 casualties every year across Britain. Self-driving vehicles have the potential to substantially reduce the number of people killed or seriously injured.[59] Furthermore, analysis suggests that robo-taxis could reduce the global average cost per mile of using a taxi, which currently stands at 4.3 times that of a private car, to just 1.2 times.[60] This would not only make transport more affordable, but also has the potential to impact the mobility of people who cannot drive, such as the elderly and disabled people.

Robotics could automate dangerous workplace tasks and help people avoid work-related injuries. Musculoskeletal problems account for a significant proportion of working-age people who are economically inactive due to long-term sickness, with 285,000 out of work due to problems with their back or neck in 2023.[61] Rates of these sorts of disorders caused or exacerbated by work are much higher in sectors with high potential for automation, including agriculture, construction and heavy industry.[62] A move towards labour being less manual could also allow more people with physical disabilities or age-related physical limitations to stay in work, helping to reduce the UK's growing levels of economic inactivity.

Much longer-term, general-purpose humanoid robotics in the home could save people significant amounts of time. In 2023 a panel of AI experts estimated that robotics will have advanced to such a degree over the next decade that they will be physically able to take on 40 per cent of the time that a typical household spends on chores.[63] Comparing their predictions for different tasks against the latest data on how long the average Briton spends on them each day, the biggest gains are likely to be in cooking (46 per cent automatable; currently taking up 48 minutes per day) and household cleaning (46 per cent; 27 minutes).[64] Given that household work is predominantly performed by women, these advances would disproportionately benefit the world's female population.[65]

Figure 1 - To varying degrees, many household tasks are predicted to be semi-automated within the next ten years



Source: TBI analysis of PLOS, "The future(s) of unpaid work: How susceptible do experts from different backgrounds think the domestic sphere is to automation?", 22 Feb 2023; ONS, "Time use in the UK: March 2024", 7 May 2024.

The extent to which households will be interested in automating such tasks, and how financially viable that step will be, will vary across society; ownership rates are unlikely to grow until the middle of this century. A useful comparison is the adoption of household appliances such as washing machines which, despite technological advances in the 1950s, did not become common in most homes until the 1960s.[66]

Short-Term Gains

While the most transformative benefits of robotics will not be realised in the next five years, there are many opportunities that will help grow the UK economy materially in the short term, primarily in the deployment of current or near-future robotic technologies.

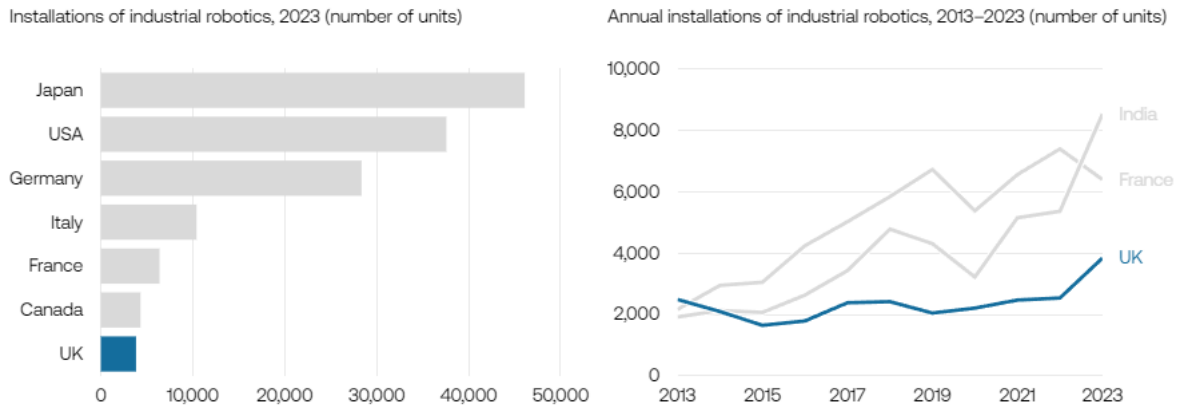
A primary example is manufacturing (and other industrial applications), where the use of robotics is expanding around the world but the UK is lagging behind. The latest figures from the IFR show that 541,000 industrial robotic units were installed in 2023, up from 178,000 in 2013, and that number is forecast to exceed 600,000 installations a year by 2027. Collaborative robots, which use AI to work alongside humans, account for a growing proportion of these installations, increasing from 2.8 per cent in 2017 to 10.5 per cent in 2023.[67]

Industrial robotics are, however, dominated by China, Japan, the US, South Korea and Germany, who together accounted for about 70 per cent of the world's installations in 2023. China alone accounted for a majority of global installations in 2023 (51 per cent), up from just 20 per cent in 2013.

By contrast, the UK recorded the lowest number of industrial robotics installations in the G7, and had fewer installations than less developed economies, including Mexico, Spain and Turkey. The IFR noted that the density of robots in the UK's manufacturing industry was 119 robots per 10,000 employees in 2023, which it described as "very low for a Western European country".

Over the past decade, the UK's industrial robotics installations have flatlined, with the UK's share of global installations halving across the period, and countries such as France and India surpassing the UK's number of installations. While the UK's installations went up in 2023, the IFR notes this is likely the result of the temporary super-deduction for machinery investments and expects installations to "decrease strongly in 2024 and slowly recover" from 2025 onward.[68]

Figure 2 - The UK was the worst-performing G7 country for industrial robotic installations in 2023 (left), and has been left behind by France and India on the same metric in the past decade (right)



Source: International Federation of Robotics, World Robotics 2024 Report, 24 September 2024

The UK's relatively low number of industrial robots is partly explainable by the fact that the automobile industry, which tends to have a higher concentration of robots, accounts for a smaller proportion of the UK's manufacturing industry. Even so, the country's automotive industry has about half the robots per employee that Germany has.[69]

Studies show that recent waves of industrial-robot use across OECD countries have had a long-term positive impact on productivity.[70] This suggests that the UK catching up with other leading economies would unlock economic gains, while falling further behind will severely damage the country's competitiveness.

Beyond industrial applications, other sectors are experiencing significant near-term economic benefits. Government-commissioned research shows that some of the greatest market potential for robotics has been realised in the warehouse and logistics sectors, where large companies such as Ocado and Amazon have been able to heavily automate their operations.

Other areas of considerable potential include the manufacturing of food and drink, the energy and infrastructure sector, and construction. Research predicts an s-shaped adoption curve across these sectors, (whereby adoption starts slow, then scales rapidly, and finally flattens with market saturation as is often the case for new technology) and that new orders will peak between 2030 and 2034. Even so, substantial growth is expected during this parliament, while the technological progress made since the research was conducted in 2021 could bring some of these peaks forward.[71]

TBI research reveals that some of the most significant time savings for the economy, achievable with current robotics technology, can be unlocked in the context of the grading and sorting of agricultural products, as well as packaging and the operation of filling machines. Workers in these occupations could double their productivity, as their roles are still dominated by repetitive manual tasks that have so far not been subject to automation.

Drones also have the potential to deliver palpable economic benefits before the end of this parliament. PwC forecasts that by 2030 there will be 923,000 commercial drones in use across the UK economy, with particularly high concentrations in the public sector, as well as the agriculture, mining, water and energy sectors, and the transport and logistics sector. The report concludes that these commercial drones will save businesses an estimated £22 billion a year, contribute £45 billion to the economy (equivalent to 1.6 per cent of projected GDP), and benefit 650,000 full-time equivalent workers.[72]

However, the near-term benefits of robotics across the wider economy remain relatively minor. Recent TBI research indicates that, aside from the growth areas set out above, only a relatively small amount of workers' time can be saved using AI-enabled robotics and other high-cost equipment using existing technologies: 0.9 per cent of workers' time in the private sector and 0.3 per cent of workers' time in the public sector, which is equivalent to the work of about 250,000 individuals. The analysis finds that many occupations could benefit at the margin from accessing these technologies but given the high investment cost, this would not be economically viable unless the tools were being used intensively.

While TBI analysis shows that the use of existing technologies only to replace worker time would grow GDP by 0.1 per cent, we expect that doubling down on automation by replacing existing machines with more effective ones would unlock productivity gains. The process of rolling out existing technologies is also likely to be slow, as only larger firms have sufficient economies of scale to invest in robotics at the current costs; prices will need to fall further for SMEs to be able to comprehensively adopt existing robotics.

Unlocking Innovation

Strategy Rethink Required

Central government support for innovation in robotics has been inconsistent, insufficient and disjointed over the past decade, damaging the UK's efforts. In 2013, the previous government recognised robotics and autonomous systems (RAS) as one of the "eight great technologies" in which the UK could be a global leader, alongside the likes of AI and quantum. However, it failed to bring forward a strategy to develop the technology.[73] Instead, in 2014 an RAS special interest group of academics and industrialists brought forward their own national strategy: RAS2020. But this strategy was never formally adopted by the government and was criticised by industry for focusing on academic pursuits instead of technology that could be commercialised.[74]

The government's 2018 Industrial Strategy Challenge Fund provided support for robotics across extreme environments, manufacturing and drone deliveries.[75] However, ministerial interest in robotics has since waned. The 2023 Science and Technology Framework did not include robotics in its list of five critical technologies, only noting in an update that there is "an enabling role played by technologies like … robotics in ensuring the success of our critical technologies".[76]

As a result of being omitted from the framework, robotics has not benefited from renewed ministerial interest in science and technology. Many experts have told TBI that government officials argue they are supporting robotics through their support for AI. While the Department for Science, Innovation and Technology (DSIT) has brought forward strategies backed by investment in other technologies – £2.5 billion for the quantum strategy and £2 billion for a national vision for engineering biology, for example – no such strategy or support is available for robotics. By contrast, China, South Korea, India, Australia and the EU have developed or are developing clear national robotics strategies, highlighting key types to develop and pull through, supported by significant levels of investment.

The new government must avoid the mistakes of previous governments in misunderstanding the importance of robotics to the future of the UK's economy, public services and society. Ministers should amend the Science and Technology Framework to specifically include robotics and embodied AI as a sixth critical technology. They should also task an independent expert from the commercial robotics industry to deliver a Robotics Opportunities Action Plan, modelled on Matt Clifford's rapid AI review,[77] focusing on how to develop and deploy the software and hardware required to realise the benefits of robotics in the UK.

Ministers will also require more expertise in the sector. Since 2019 the government has benefited from the advice of the Robotics Growth Partnership, an independent advisory body comprising experts from academia and industry. But given there is reportedly just one robotics specialist within DSIT itself,[78] the department needs to hire more specialists with first-hand experience of robotics and industry.

The Crucial Role of Universities

One of the UK's strengths in robotics is its universities. In recent years, several leading robotics companies have been spun out of universities: examples include Oxa, the autonomous-vehicle software developer, and Acuity Robotics, which uses robotic systems to monitor critical infrastructure.[79] University College London, meanwhile, has recently developed advanced haptic sensors that can deliver simultaneous stimuli across multiple fingertip areas.[80]

However, broad pressures on universities are slowing down research. Experts have told TBI that financial constraints are leading robotics researchers to charge for higher overheads in grant requests, pricing universities out of the process. Leading universities are also having to levy higher equities on spinouts, with a recent report showing that they take an average 21.7 per cent stake in hardware spinouts and 20 per cent stake in software companies.[81] This renders such spinouts less likely to become major players in the market and more likely to be acquired by third-party companies that are often based outside the UK, as high dilution means subsequent funding is harder to raise and founders are more likely to leave.

Bureaucracy within universities is also leading to grant-application deadlines being missed, and researchers told us that teaching and admin responsibilities are increasingly cutting into research time. In *A New National Purpose: Innovation Can Power the Future of Britain*, some of the proposals around slimming down the audit culture in universities, alongside further reforms to spinout practices, would help address some of these issues.

Getting Research Funding Right

The above issues are compounded by issues around how government funding for robots is spent. The main vehicle for investing in robotics has been UKRI, via its Challenge Fund. The organisation has invested in three challenges specific to robotics (Future Flight, Robots For a Safer World and Self-Driving Vehicles), along with other challenges in which robotics has a key role (Made Smarter Innovation and Transforming Food Production). Funding for two of these challenges expired in 2022 with a further two expiring this year, with no new plans announced.

Despite some successes, including investment in robotics research hubs and support for the creation of a drone superhighway, concerns have been raised about how the Challenge Fund investment is being spent.[82] The National Audit Office has warned that UKRI needs to put more emphasis on the impact that its funding secures, and highlighted that it takes an average of 31 weeks for it to assess applications for project funding.[83] These issues seem to be particularly acute within robotics, with a number of experts we spoke to warning that investment via UKRI is often not joined up, with lots of spending going into different universities working on similar projects that are never commercialised.

Figure 3 - How the UKRI Challenge Fund has been distributed across robotics projects

	Future Flight Challenge	Robots For Safer World Challenge	Self-Driving Vehicles Challenge	Made Smarter Innovation Challenge	Transforming Food Production Challenge
	2019–2024	2017–2022	2017–2022	2020–2025	2019–2024
Budget	£125m	£112m	£28m	£147m	£90m
Key outcomes	Supported the use of drones to deliver medical supplies and created a 165-mile drone superhighway connecting the Midlands and South East.	Invested in four robotics research hubs to specialise in different use cases across space, nuclear energy and offshore infrastructure.	Funded three self-driving projects, including one for self-driving vans that could help bring the technology to the light-commercial-vehicles market.	Supported the Made Smarter Innovation Centre for Smart, Collaborative Industrial Robotics.	Backed 15 projects involving robotics in food production, including investments in berry-picking machines, vision-guided weeding machinery, and dairy milking.

In a similar vein, UKRI investment in robotics and autonomous systems via its Strategic Priorities Fund is particularly poorly targeted. Neither of the two programmes specific to this field are focused on commercialising autonomous robotics to improve productivity, despite funding coming from the government's National Productivity Investment Fund. The £9 million Living with Machines programme focuses on the social impact of automation during the first industrial revolution, while the £34m Trustworthy Autonomous Systems programme focuses on potential impacts of autonomous systems on wellbeing, personal freedoms and society.[84]

The work of Innovate UK's Catapult Network has been more impactful. The High Value Manufacturing Catapult is driving forward research in robotics and helping businesses to deploy automation within their organisations;[85] the Connected Places Catapult is supporting robotics in transport through the Drone Pathfinder Catalyst Programme.[86] In addition, the Robotics Proving Ground launched in early 2024 by a group of catapults could improve the way robotics is tested and validated.[87]

While UKRI's programmes have an important role to play, additional models of organisation and funding will be required across three areas.

1. Mission-Driven Research

As has been argued across our series of joint New National Purpose reports, the best way to unlock innovation is through long-term funding for relatively small teams of highly talented individuals entrusted with the operational freedom to invest their budgets as they see fit. Experts in this sector concur, with the Robotics Growth Partnership highlighting the benefits of a "Smart Machines Centre of Excellence … modelled on invention institutes such as Bell Labs and Xerox Parc" in its recent consultation.[88]

ARIA, which is a good example of the kind of model required, is leading innovative research into robotics hardware. The agency has warned that, despite continued progress on AI models for robotics, the momentum on hardware capabilities has stalled; as such it is investing £57 million in a programme called Robot Dexterity, to ensure that robots achieve the required flexibility, speed and precision (equivalent or superior to human manipulation) to automate difficult and dangerous tasks.

The programme hopes to create one or more robotic manipulators with increased dexterity over existing approaches, alongside delivering new techniques for designing robotic hardware and control software. It further seeks to yield advances in associated technologies such as actuation and haptic sensing.[89] ARIA is also investing smaller seed funding in ideas that can deliver within its Smarter Robot Bodies opportunity space, which is outside the scope of its dexterity programme.[90]

2. Improved Support for Startups

An interesting model is being pioneered by the National Robotarium on Heriot-Watt University's Edinburgh campus. Initially started with £22.4 million in capital funding from the UK and Scottish governments, the robotarium supports startups in developing their products; it also helps them scale by facilitating introductions to investors and external capital. It is home to research projects, and helps companies understand how to adopt robotics to improve their business. The day-to-day operations of the robotarium are financed via three methods: funding from companies looking to adopt robotics; the renting of spaces to businesses and researchers; and the selling of access to the robotarium's lab settings for designing, building and testing robots, including the Robotics and Autonomous Systems Laboratory.[91]

Having only opened in 2022, the impact of the robotarium's model in helping to commercialise robotics is still being established – but its progress is encouraging. It has supported the launch of numerous innovative products, including Crover's grain robot – which is able to swim through stores of grain to check temperature and moisture levels – and Touchlab's Välkky telerobot, which allows operators wearing an advanced electronic haptic glove to remotely perform simple nursing tasks on infectious patients.[92]

The National Robotarium has called for more robotariums to be created across the UK, to help more robotics researchers start commercialising their ideas.[93] Ministers should consider this proposal as more evidence of the impact of the National Robotarium comes through. Creating a network of robotariums and establishing solid communication lines between them

could help prevent the duplication of research under existing granting frameworks. Situating them in the vicinity of other universities that lead on robotics would also allow more university researchers to access world-class robotics laboratories.

3. Open-Source and Modularised Robotics

More funding could be targeted towards creating open-source and modularised software and hardware components that could be used across different domains of robotics. As the Robot Growth Partnership has argued, these technologies could act as "Smart Machines Lego", providing researchers and startups with adaptable building blocks for developing more complex robotics in less time and at a lower cost.[94] Of course, given that open-source technology comes with risks (including cyber-vulnerabilities and use by malicious actors), controls would be required.[95]

To deliver on this, our proposed Robotics Opportunities Action Plan could explore the key software and hardware components that robotics startups in the UK require most at present, identify areas where modularised components could generate significant cost and time savings, award grant funding for developers to produce these components and, when delivered, make these components open-source to support UK startups.

Accessing Talent

The UK's robotics industry is dependent on international talent for both hardware and software expertise. In the past four quarters, the government has granted 6,100 worker visas to engineers and 14,800 to IT professionals, including 1,000 visas for mechanical engineers and 5,700 for programmers and software developers, the skills most required for robotics.[96] To compound matters, a minority of postgraduate researchers studying mechanical engineering or computing at university are from the UK (about 45 per cent in both cases), compared to three-fifths across science postgraduate researchers in general.[97] Plus, many of the best researchers with expertise in AI that the UK does have decide to work in high-profile software-only sectors instead, such as foundation-model or generative-AI development, as this is a faster route to high pay and prestige than robotics.

The government has recognised the UK's reliance on international talent, with the home secretary recently asking the Migration Advisory Committee to investigate which roles in engineering and technology are struggling with shortages, and whether pay, training and conditions explain these shortfalls.[98] While more action on cultivating home-grown world-class talent in robotics would be welcome, this would be a decades-long endeavour.

There are concerns within the UK robotics industry that any measures that directly reduce access to international talent would damage the sector, particularly as developing robotics hardware and training AI for robotics are highly specialised roles that are often difficult to fill as it is. Instead, ministers must build a long-term pipeline of skills by working on encouraging more Britons to go into robotics, as well as continuing to make it easy for world-class talent to come to the UK.

Early engagement with UK school children through programmes such as the First Robotics competition can spur interest in the field.[99] Raspberry Pi, one of the UK's most significant computer companies, started as an effort to get children to code and build with computers. The UK can do more to celebrate and deploy the legacy of this distinctly British firm in order to encourage more children to get into hardware and robotics development.

In higher education, the vast majority of Russell Group universities only offer robotics courses at master's level,[100] meaning that most undergraduates end up specialising in either hardware- or software-focused domains. Government support for new undergraduate courses in robotics, similar in nature to the ones that the Robotics Institute Germany is developing,[101] can help more young people to develop expertise in both the hardware and software, as well as how they interact; this will result in a pipeline of future robotics experts who can be called upon. While new degree apprenticeships for robotics were approved by the Institute for Apprenticeships and Technical Education earlier this year, their launch has been delayed[102]. Meanwhile, UKRI could consider expanding its funding for the five Centres for Doctoral Training relevant to robotics.[103]

In *A New National Purpose: AI Promises a World-Leading Future of Britain*, we called for new polymath fellowships to help specialists in one field gain technical expertise in another. This could help researchers to transcend the traditional divide between hardware and software, establish skills across both and engage in more studies and projects that combine both.

Building the Digital Infrastructure

More must be done to ensure that robotics researchers can access the data they need to train their models to deliver embodied AI. There are huge amounts of text and image data online that can be used to train LLMs; there is scant accessible data for teaching robots how to move and recognise what is happening around them.

While robotics companies such as Google DeepMind are teaching their robots to pick up visual data as they go, the scale of the data challenge remains enormous. Well-known computer scientist Hans Peter Brondmo has argued that it will take deploying "many thousands, maybe even millions of robots doing stuff in the real world" to collect enough data to train them to do more than generally well-defined, narrow tasks.[104]

Moreover, data access can be a major inhibitor for startups and researchers. It is expensive and operationally complex to collect data from observing the world; developers must also purchase data from other third-party sources, which can be costly to acquire, transfer and store on the cloud, as well as being beset with data-privacy challenges. These inhibitors, together with the fact that there aren't many publicly available data sets for researchers to use, can act as a significant barrier.

Health care is an area in which the government could play a key role in improving data collection for robotics. As we outlined in *A New National Purpose: Harnessing Data for Health*, the NHS hosts a trove of data that could be used to develop AI for medical applications and improve health-care provision.

To help achieve this, ministers should explore the creation of data sets around the use of robots in health care, which could be made available for researchers and startups working in this area. For example, firms trialling the use of cleaning or delivery robots in NHS hospitals could be required to share a proportion of the data they generate with a sovereign NHS data source. Similarly, data generated by robot-assisted surgeons in the NHS could be pooled, stored and used in future to develop better – and more autonomous – robotic systems; these would help surgeons increase precision, flexibility and control for many procedures.

Patient consent would need to be secured for any medical data collected, and would need to be stored securely and subjected to strict safeguards. Access to this data would then be granted through the National Data Trust, as proposed in *A New National Purpose: Harnessing Data for Health*.

Last but not least, the necessary compute to train robotics software models can be difficult for startups and researchers to access; the government's reported interest in increasing support for the UK's sovereign compute capacity is therefore welcome. To ensure maximum benefit for the robotics industry, state-backed compute infrastructure should be accessible not only to universities and other research organisations, but commercial startups too.

Enhancing Pull-Through Capabilities

Capital For the Long Haul

Given the constraints on the public finances, most of the funding to commercialise and pull through robotics in the UK will have to come from private capital. Ongoing reforms to unlock more private capital for UK startups, including reforms to pensions (as outlined in *Investing in the Future: Boosting Savings and Prosperity for the UK*), will therefore be critical to seeding early-stage robotics companies.

Unless these reforms are prioritised, the intimidating "valley of death" faced by deep-tech, robotics and hardware startups seeking early-stage funding will be an issue that remains unaddressed. This gap between development in academic contexts that is funded by UKRI, and late-stage commercialisation supported by growth capital, remains particularly stark in the UK.

While access to capital is a challenge across the UK's tech ecosystem, it is a particularly significant one for robotics due to hardware costs, data constraints and the higher levels of verification and validation to prove safety and reliability. Products requiring hardware have longer development times and higher production costs than purely software-based products, meaning they can take a lot longer to become profitable. Software also tends to be easier to rework in line with customer feedback, making it more straightforward for businesses to integrate it into their operations. Hardware is also more dependent on supply chains than software, and lacks the effortless scalability of software. The latter can be copied an unlimited number of times at virtually no cost, enabling fast, exponential growth and outsized returns.

For these reasons, venture-capital investors (VCs) outside the US and China (where large funds have the resources for longer-term, riskier investments) remain reluctant to invest in robotics. Internationally the investment outlook is improving, with data from private-company database Beauhurst showing that deals for robotics and drones in 2024 are on track to overtake the $9.7billion raised in 2023.[105] That said, the extent to which investment in robotics in the UK is increasing is unclear.

Securing sufficient capital to scale is a challenge. As a result, it is substantially more difficult for young robotics startups that are based and deploying in the UK to move from pre-seed and seed to growth stage (Series A onward) than it is for their peers in China and the US. The disparity in availability of patient, private capital also means that early-stage robotics startups in the UK are more likely to be acquired by foreign entities, and their technologies subsequently moved abroad.

Aside from Britbots, a VC focusing specifically on automation technologies designed to enhance productivity,[106] there are relatively few funds investing in robotics startups in the UK. The UK's long-term lack of patient capital led to the previous government creating British Patient Capital (BPC) in 2018, a £2.5 billion fund linked to the British Business Bank. The aim of BPC is to crowd in private capital and provide startups in the UK with access to

longer-term growth-stage investment, in order to help such startups scale.[107] The 2020 Budget included a £200 million Life Sciences Investment Programme within BPC, to support health and life-science innovations.[108] Given the challenges involved in accessing capital for robotics companies that create products requiring hardware, the government should consider creating a similar Robotics Investment Programme through BPC, which would help hardware and robotics startups in both their early and growth stages. This would expand beyond the BPC's original focus on ventures in their growth stage, supporting UK robotics startups across their lifecycle; this would also further address the UK-wide early-stage funding gap.

As highlighted in *A New National Purpose: Leading the Biotech Revolution*, state capital investment in startups tends to work best when deployed in the form of follow-on funding rather than lead funding. As such, the proposed Robotics Investment Programme should be a follow-on fund that invests in UK robotics companies that have already secured external capital from a lead institutional investor. Such a vehicle could offer significant long-term returns for the government, as it could take equity alongside and on the same terms as its private partners, returning capital to the taxpayer.

Alongside this, the government should consider another recommendation in *A New National Purpose: Leading the Biotech Revolution*: to uprate the Venture Capital Trust scheme limits for knowledge-intensive companies, allowing robotics startups to benefit for longer from tax reliefs on the scale-up capital they raise. Together with the maintenance of existing R&D tax incentives, these interventions can help ensure that robotics startups can access the capital they need to grow and scale.

Procurement That Is Fit For Purpose

Given the importance of robotics for public services, the government can use procurement to make sure that public bodies such as the NHS, police and local authorities have access to smart robotics, while also providing scaleups with a stronger market of potential customers. Procurement can also help reduce the cost and risk of innovation – as well as the time spent on it – by building shared components and platforms that can be reused across different sectors, public services and use cases, thereby seeding an underlying market that industry can build upon and invest in.

The UK's procurement system model is ill equipped to procure next-generation technologies. In *Reimagining Procurement for the AI Era*, TBI called for an Advanced Procurement Agency to transition new and emerging technologies into public institutions faster and drive innovation across government. Alongside these broader reforms to procurement, the government should also consider specific interventions around robotics.

Ministers could create targeted funding programmes to help public bodies to fund robotics initiatives that will solve challenges in their operations. The UK has a good record here, with Innovate UK's Contracts for Innovation (formerly known as the Small Business Research Initiative) awarding £788m in competitions for public bodies between 2008 and 2020.[109] Some of these interventions have supported robotics, including autonomous vehicle software for the Defence and Security Accelerator and funding for Apian's trial to deliver

medical supplies by drone.[110] However, given the importance of stimulating the UK's robotics market, the Robotics Growth Partnership is right to ask whether a tailored Contracts for Innovation-style programme for smart machines could help spur investment by the private sector.[111]

The government should also explore the use of AMCs to pull through emerging capabilities in robotics. These work by setting out a commitment to purchase or subsidise a product if someone can invent and produce it to a high standard, and have been used successfully in the past to galvanise the creation of new vaccines.[112] Innovate UK has recently formed an alliance of major concrete users, the Concrete Commitment Cohort, to support an AMC to produce concrete that is less carbon intensive.[113]

To make the best use of AMCs, ministers should first identify the key areas in which robotics are possible in the short term and would unlock public benefits. This exercise could be performed as part of the rapid Robotics Opportunities Action Plan proposed above; it could also be informed by other experts such as the robotics team at ARIA, with potential AMCs centred around the government's priorities for public services. These AMCs could include, for example, bringing together NHS trusts to purchase robots for automated laboratories, operators of materials-recycling facilities to purchase robotics for autonomous recycling, local authorities to purchase self-driving buses, and large farms to purchase robotics that can perform the work of low-paid seasonal workers.

Finally, the government could consider establishing training programmes for public-sector procurement teams, such as NHS Supply Chain[114], to support them in identifying the types of public-sector challenges that could be solved by integrating robotics into their operations.

Boosting Awareness to Highlight Incentives

Making companies aware of the potential productivity benefits of integrating robotics into their workflows, and supporting them in overcoming the upfront costs of doing so, will be critical to realising the economic benefits of these technologies and creating a pipeline of customers for startups.

At present, awareness and incentivisation are limited. Experts we spoke to reported that most SMEs do not feel confident in their ability to identify and engage with robotics products that can support their businesses; lacking what they believe to be the required expertise, they are having to rely on expensive consultants instead. The Robotics Growth Partnership has noted that a "significant barrier to adoption of Smart Machines is the inability of organisations, across both the private and public sectors, to grasp the 'sense of the possible'". Due to high upfront costs and this knowledge barrier, robotics adoption remains concentrated in sectors of the economy that are dominated by large companies. The main example is the automotive sector, which accounts for 46 per cent of the UK's operational industrial-robotics stock.[115] Meanwhile, adoption remains low in the sectors of the economy where the largest productivity gains can be made, such as agriculture.

In recent years the government has taken steps in the right direction. Ministers have trialled a Made Smarter Adoption Programme in the North West since 2019, through which

manufacturing SMEs are given expert advice and match-funded grants to support the adoption of industrial digital technologies (IDTs), including robotics. The pilot has supported more than 500 IDT projects, leveraging £20 million in private investment, and provided 900 businesses with digital roadmaps for integrating technology into their operations.[116] Furthermore, the International Federation of Robotics has noted that the previous government's super-deduction for capital investments likely benefited robotics adoption in the automotive industry.[117]

Going further, the previous government planned to expand the Made Smarter Adoption Programme, seeking to deploy £16 million in 2025–26 across the rest of England. The government should follow through on this commitment and explore the possibility of funding similar initiatives in other sectors. Given that recent reviews have found that knowledge barriers are a particular challenge to automation in the agriculture sector,[118] this would be a good additional sector in which to roll out support.

Equally critical will be avoiding the introduction of any disincentives to investing in robotics, such as a "robot tax". It is likely that future advances in robotics and automation will create new funding challenges around reskilling and disrupt the tax system, which is heavily reliant on income-tax receipts.

Bill Gates called for a robot tax in 2017, arguing that labour performed by robots should be taxed at similar levels to the work performed by human employees. Gates went on to suggest that even if such a tax slowed down innovation, this would be acceptable as it would help reduce people's fears about automation.[119] To date, the only country that has taken any action along these lines is South Korea, which reduced its automation tax credit in 2018 to slow the rate of automation within its manufacturing sector.[120]

The government should resist any move towards a "robot tax". As Rachel Reeves wrote in her report on automation for the Business, Energy and Industrial Strategy Committee in 2019, "We need more robots and not fewer. A tax on them would further discourage take up."[121] Furthermore, as economist Daniel Susskind has argued, robots can complement workers as well as replace them, and "since it is hard to disentangle these effects" it would be difficult to tax robots in a way that "put a penalty on the harmful ones rather than the helpful ones".[122]

Responding to calls for a robot tax in 2023, the Labour frontbench made clear that it had "no plan to tax business for using AI".[123] This position should be maintained, in order to avoid disincentivising investment in tech as new forms of taxation are necessarily developed.

Striking the Right Balance on Governance

Resetting Regulation

One of the key structural barriers that the government must work to address is regulation. Many experts have warned that regulators are struggling to keep up with advances in robotics, and a lack of coordination between different regulators is holding back innovation. Studies show that some of the key future regulatory issues around robotics will relate to accountability, liability and data privacy, with additional risks around exploitation by malicious actors.[124]

Aside from removing barriers, regulators also have an important role to play in introducing new rules that can create greater certainty around emerging technology, as well as crowding in private investment. The best recent example of this is the Automated Vehicles Act 2024, which requires self-driving vehicles to achieve a level of safety at least as high, careful and competent as human drivers, while allocating liability to manufacturers. The act paves the way for self-driving vehicles on UK roads by as early as 2026, by creating certainty around legal liabilities. By setting out clear regulation around safety, the act will minimise the risk of accidents that could reduce public trust in the technology.[125]

Drones are another area in which some progress is being made on regulation. The Department for Transport (DfT) has published a UK Future of Flight Action Plan, setting out the ambition to allow drone operations beyond visible line of sight (when the operator can no longer see the drone) at scale by 2027 – although it is yet to flesh out a clear vision of how to get there. The Civil Aviation Authority (CAA) is also supporting 12 trials to test the use of drones in deliveries, infrastructure inspections and emergency services.[126]

Recent reports have also highlighted ways forward in other sectors. The Regulatory Horizons Council recently reported on removing regulatory barriers to autonomous robotics in agriculture and horticulture, including via sandboxes, data standards and liability arrangements, all of which will drive progress in this area if actioned by the government.[127] A Treasury review of the regulation of advanced manufacturing has called for ministers to work with the British Standards Institution and Health and Safety Executive (HSE) to develop clear standards around the deployment of cobots (collaborative robots) in manufacturing.[128] Standards are also being developed within industry, with one example being the Institute of Electrical and Electronics Engineers' introduction of standards around the ethical use of robots.[129]

However, as technological developments in robotics continue to accelerate, regulators will need more support to ensure that they can respond rapidly and position the UK at the forefront of these advances. They will need the resources, capacity and expertise necessary to both review and remove barriers, while introducing new rules that provide robotics developers, investors and the public with greater certainty.

Sector-specific regulators need more support. Multiple experts told us that regulators would be better able to respond to developments and secure first-mover advantages for the UK if

they had suitable financial resources and technological expertise to draw upon. While we recognise the government's financial constraints, a relatively small amount of additional funding for these regulators, specifically geared towards unlocking expertise and know-how, could unlock numerous economic benefits over the next decade.

Ministers should seek to ensure that regulators such as the Vehicle Certification Agency (VCA), the Driver and Vehicle Standards Agency (DVSA), the CAA and the HSE are sufficiently resourced. The government should also explore the proposal of Government Chief Scientific Advisor, Professor Dame Angela McLean, who argues for a robotics secondment scheme within the HSE, which could act as a pilot scheme for bringing industry experts into other regulators.[130]

Sector-specific regulators also need more coordination. For example, delivering medical supplies by drone requires the approval of a range of different regulators with different requirements, including the CAA, the Medicines and Healthcare products Regulatory Agency and the Human Tissue Authority. In such cases, clearer and more cohesive regulatory frameworks could reduce regulatory burdens on robotics suppliers. Furthermore, experts told TBI that improved coordination will be necessary to govern how these technologies intersect with one another; for example, how an autonomous ship docks with an autonomous port to offload its cargo to autonomous delivery drones.

The government's commitment to creating a Regulatory Innovation Office and expand the Regulatory Horizons Council can help in this regard, provided that ministers set robotics as a strategic priority.[131]

Addressing Social Attitudes

Data are clear that in specific sectors, trust in the safety of autonomous robotics remains an issue. YouGov data show that most Britons say they would feel unsafe in a self-driving vehicle – and public opinion on this has not changed significantly in the past five years.[132] Recent polling also shows that the public recognises the benefits of drones but is concerned about safety and the potential for crowded skies.[133]

While safety concerns should decrease as these robots become more common in day-to-day life, premature release could damage long-term trust in smart robotics. For example, Americans' reported trust in self-driving cars fell sharply in 2018 after a series of high-profile crashes.[134] High safety standards and proportionate regulation are therefore critical to protect demand for robotics.

Research suggests that Westerners have a cultural aversion to some robotics – and particularly those with a humanoid appearance. Polling by Brookings has found that many Americans (61 per cent) are uncomfortable with robots in general.[135] But a recent study found that Americans, compared with Japanese, are more comfortable with robots that don't have a human likeness; the study suggests that this is probably a result of differing cultural traditions.[136] Meanwhile, academics have warned that humanoid robots may lead to greater anthropomorphising of robotics, creating fresh ethical issues.[137]

The impact of robotics on the job market is another concern for the public. A 2017 poll found that 72 per cent of Europeans (including 63 per cent of Britons) agreed that "robots and artificial intelligence steal people's jobs".[138] Based on a different survey, the proportion of UK respondents who are worried that their type of work could be automated within their lifetimes has risen over the past five years (28 per cent, up from 18 per cent).[139] Tied up with this are concerns that automating specific tasks around caring for children, the elderly and the vulnerable could also damage human dignity.[140]

The Robotics Growth Partnership has argued that societal attitudes around robotics "must move beyond narratives of unemployment and Terminator".[141] Safety concerns can be addressed by fast-moving regulation that strikes the right balance between innovation and upholding high safety standards, along the lines outlined above.

On automation, the government can move the public conversation forward in several ways. First, a focus on using robotics to automate dull, dirty and dangerous tasks – what experts have called the "three Ds" of robotics. A poll found that 84 per cent of Europeans agree that robots are necessary for jobs that are too hard or too dangerous for humans.[142]

Second, greater emphasis should be placed on how human workers can be empowered by robots. Rather than doing a task themselves, future workers may be supervising teams of robots, resulting in jobs that offer more responsibility, as well as being more fulfilling and better paid. At least in the short-term, many jobs will also be created by advances in robotics, in the context of servicing and upgrading robots.

Third, proposals put forward in *A New National Purpose: AI Promises a World-Leading Future of Britain* on responding to automation, such as long-term planning for a retraining fund, would also help manage the impact of robotics on the labour market and allay public concerns.

Exporting Robotics

Significant scaling of the UK's robotics industry will need to result in something that can be exported to the rest of the world, which means the government has an important role to play in supporting fast-growing businesses. Aside from the benefits for economic growth, the export of robotics could become an important aspect of the UK's development policy. A study has found that robotics could support 46 per cent of the UN's 169 sustainable development goals, with the biggest benefits around food security, energy and infrastructure.[143]

Regulators can promote the UK's approach to regulating robotics abroad, making it easier for UK companies to meet the needs of international markets as well as raising safety standards around the world. Some regulators that deal with embodied AI are already excelling in this space. For example, the VCA has offices around the world and works closely with the standards teams within the DfT to provide expertise on global automotive regulations, most notably within the United Nations Economic Commission for Europe's discussions on technical specifications for self-driving vehicles. Encouraging more robotics

regulators to follow its lead will require government help in ensuring that regulators are sufficiently well resourced.

In addition, expertise and relationships in government can be better deployed to connect robotics companies with regulators and agencies within international markets. This could be achieved by expanding the use of relationship managers, or through a new Concierge Expansion Service for UK scale-ups.

Recommendations

Here we summarise the key actions that should be taken by the UK government. And to note, while this report has been particularly focused on the next wave of robotics, driven by AI, a number of these recommendations would also benefit other forms of robotics, including those that are manually programmed or remotely operated.

Innovation

- **Amend the Science and Technology Framework** to specifically include robotics and embodied AI as a sixth critical technology. Task an independent expert from the commercial robotics industry to deliver a Robotics Opportunities Action Plan, focusing on how to develop and deploy the software and hardware required to realise the benefits of robotics for the UK.

- **Expand the robotics team at DSIT** by hiring more specialists in robotics software and hardware. Prioritise robotics specialists in existing schemes, such as the DSIT Science & Technology Fellowship,[144] to bring experts from the industry into the department.

- **Review government investment programmes for robotics research**, reallocating some of the funding from UKRI for new approaches. This should include:
    - additional grant funding for ARIA to support its Smarter Robot Bodies opportunity space
    - exploring future capital funding for a network of National Robotariums
    - Grant funding for the creation of open-source and modularised software and hardware, to help researchers and startups develop more complex robotics in less time for lower cost

- **Support more people in gaining expertise in different aspects of robotics** through engagement projects with school children, work with a leading university to pilot a robotics undergraduate course and introduce polymath fellowships for robotics, requiring UKRI to expand support for centres for doctoral training relevant to robotics.

- **Explore the creation of new NHS data sets for the use of robots in health care**, subject to strict safeguards around patient consent, secure storage and access. For example, collecting data from robot-assisted surgeries that could be used to train autonomous robotic surgeons.

Pull-Through Capabilities

- **Create a £100 million Robotics Investment Programme** through British Patient Capital, providing follow-on funding to support early-stage and growth-stage robotics startups.

- **Explore the use of a targeted Contracts for Innovation programme** to help public bodies fund robotics initiatives that can solve challenges in their operations.

- **Use AMCs to pull through emerging capabilities in robotics.** Use the proposed rapid Robotics Opportunities Action Plan to identify key potential deployments according to key public needs. Coordinate key potential purchasers to provide AMCs for different potential uses, such as bringing together NHS Trusts to set an AMC for automated labs.

- **Consider establishing training programmes for public-sector procurement teams,** such as NHS Supply Chain, to support them in identifying the types of public-sector challenges that could be solved by integrating robotics into their operations.

- **Confirm the £16 million to roll out the Made Smarter Adoption Programme across the rest of England** and explore a similar Grow Smarter Adoption Programme for the agriculture and horticultural sectors.

- **Resist any moves towards a robot tax**. This position should be maintained even if future automation leads to significant funding pressures and tax disruption, in order to avoid disincentivising investment in tech as new forms of taxation are necessarily developed.

Governance

- **Increase financial support for regulators where new uses of robotics and embodied AI are transforming sectors**, such as the VCA, DVSA, CAA and HSE. Implement Angela McLean's proposal for a robotics secondment scheme within the HSE, to act as a pilot scheme for bringing experts into regulators.

- **Improve coordination across regulators dealing with robotics** by delivering on the proposed Regulatory Innovation Office. Set the deployment of robotics, including self-driving vehicles and drones, as a strategic priority for this new office.

- **Address societal concerns concerning robotics and automation** by focusing interventions on automating dull, dirty and dangerous tasks. Start long-term planning for how a retraining fund for those whose jobs are displaced by robotics could work.

- **Expand the use of relationship managers or set up a new concierge expansion service for UK scaleups**, to help connect robotics companies seeking to export with regulators and agencies in international markets.

Conclusion

As articulated by Alex Kendall, cofounder and CEO of Wayve, “Twenty years from now, if you ask someone about AI, most people will associate it with physical robots that enhance their lives.”[145]

Spearheading this new wave of robotics is a considerable opportunity for the UK, with the potential to benefit the economy, public services and society as a whole. Failing to act now will result in other countries reaping the largest economic benefits, with the UK having little influence over how the technology is regulated. Lagging behind in robotics would also pose a serious risk to national security.

The government needs to leverage the UK’s strengths in AI software while mitigating a relative weaknesses in robotic hardware, through reforms in innovation, pull through and governance. This will result in the prospect of leading in robotics and delivering a better future for the country.

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