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AUTOMATION TO AUTONOMY:
NAVIGATING THE PATH TO SUCCESS

CONTENTS

EXECUTIVE SUMMARY

The pathway from automation to autonomy – and on to commercial success – needn't be daunting. We are living through a time of unprecedented change, with the events that began in early 2020 sparking the greatest acceleration of digital adoption in living memory.

Everyone knows that phenomenal advances in artificial intelligence, robotics, wireless connectivity and edge computing are opening up transformative commercial opportunities. Now is the time to seize them. This whitepaper sets out to provide a springboard to the future, by offering a practical guide on how to successfully navigate the road to automation and autonomy.

Our first rule is an important one: there is no straightforward, one-size-fits-all, off-the-shelf solution. Instead, we advocate a bespoke approach focused on a clearly defined business goal. The paper will explore relevant success stories in the logistics and automotive industries, reveal parallels to other industries, and examine three levels of emerging, maturing and advanced adoption. There are plenty of lessons to be learned within each, but ultimately the journey to successful automation and autonomy will be yours and yours alone. The overview of relevant technologies we provide, drawn from our deep expertise, acts as a foretaste of the game-changing business breakthroughs yet to come.

1 INTRODUCTION

For a while, the pandemic hit the world's pause button, and the image froze. But a great acceleration simply had to come. Every recession has always quickened existing trends. Now, the fast-forward button has been pressed for us. The current global recession is no different to what we've experienced in the past, just more extreme – with huge falls followed by huge upticks, all within the space of 15 to 18 months. But we are riding a pace of change more rapid than anything in living memory. As momentum quickens, the flexibility and availability of unskilled labour continues to decline. And even at a time when money is tight, the desire to innovate to survive and prosper in the longer term is overwhelming. Something's got to give, and greater automation stands ready to come to the fore.

Since the first industrial revolution, the business case for overcoming a lack of available labour and skills by doing things more efficiently has always been strong. But it has never been as irresistible as it is now. At the same time, the breadth of available technology and the myriad of ways it can boost the bottom line has never been so wide. Yet for all that, many organisations are still holding back. They know that the pathway from automation to autonomy is paved with huge benefits, but they are still reluctant to move.

A big part of this could be put down to unfamiliarity. Perhaps that chimes with you. Maybe you are part of an industry underwhelmed by automation, and which views it as complicated, expensive and uncertain in outcome. If that's the case, please regard this paper as a roadmap for your route ahead, a touchpoint for your ambitions and a directional aid on how to take the first steps.

We plan to provide insights and answers along the way. Digitalisation, for instance, is a trend that has been accelerated by the pandemic, but what does it actually mean in practice? The goods you order online, the food you eat and the vehicles that deliver both have had to evolve rapidly and will continue to do so over the next decade. How do you compete in this ever-changing world? The answer is to establish precisely how automation and intelligence can bring unique value to your business – and deliver on its promise without you having to spend a fortune on R&D activities.

"many organisations are still holding back. They know that the pathway from automation to autonomy is paved with huge benefits, but they are still reluctant to move."

Image courtesy of Ocado Group

2 THE AMBITION

First let's be clear about what we mean by automation and autonomy. The former relates to the employment of machines and processes to replicate a series of manual tasks. The latter is an elevation of that, perhaps best defined as automating a series of complex activities using machine intelligence to achieve the task in hand, with what might be termed self-governance. The technologies enabling these solutions can be truly transformational for ambitious companies. Globally, there are numerous instances of organisations leapfrogging their competitors on the back of bold breakthrough innovation.

The Ocado Smart Platform (OSP), for example, is Ocado Group's world-leading suite of solutions that has been built to transform online grocery across the world. The OSP combines Ocado Group's proprietary end-to-end software systems with their physical fulfilment assets to deliver superior economics for grocery retailers and unmatched experiences for consumers. As a strategic OSP technology partner, we worked alongside Ocado Technology to develop the unique communication system that sits within the OSP, orchestrating swarms of bots across highly automated warehouses.

Others have identified the right level of automation and autonomy for their business – and acted accordingly. This is a key but often overlooked point. There is no such thing as a one-size-fits-all approach to automation. Indeed, the most powerful way to avoid the obstacles to greater automation is to invest time upfront on establishing a bespoke strategy to meet your needs. Where to start? We advocate beginning by getting a fix – and perhaps identifying your place – on the automation to autonomy spectrum.

As the chart here shows, it's possible to define three levels of automation and autonomy, broken down into a data stage, a data plus process stage and a data, process, action stage. The first could be described as 'semi-intelligent' in that the system collects and logs data about its performance but does not have the ability to make any decisions. Often, the data will be used in the future to improve efficiency.

At the second 'intelligent' or 'semi-smart' level – data plus process – the system collects data and processes it into real-time actionable information. This is then used by the system or a human operator to make optimal decisions. The third 'smart' level adds the action. Here, appropriate actions are taken in a way that is completely autonomous, dynamic and adaptive to changing operating conditions.

Despite what some might believe, automation and autonomy is not about replacing humans, it is about augmenting an existing labour force or individual with data, insight and tools which improve efficiency and productivity. This is reflected in our spectrum, which in the simplest terms can be thought of moving from raw data to insight, to response. A good way to illuminate this further is to consider the Levels of Driving Automation standard for self-driving vehicles published by SAE International, the global association of engineers and related technical experts in the aerospace, automotive and commercial vehicle industries.

Traditional manual motoring is level zero, with the driver fully responsible for all aspects of control. At level one, the driver can delegate one of the driving tasks to the system, while at two, the driver is monitoring as the system performs several tasks. At three, the driver can turn their attention away, as the system controls the vehicle on defined routes. At level four, the driver can hand over complete control (and take it back whenever they wish) while the system performs all the tasks. At five, no driver is necessary as the system controls the vehicle autonomously at all times.

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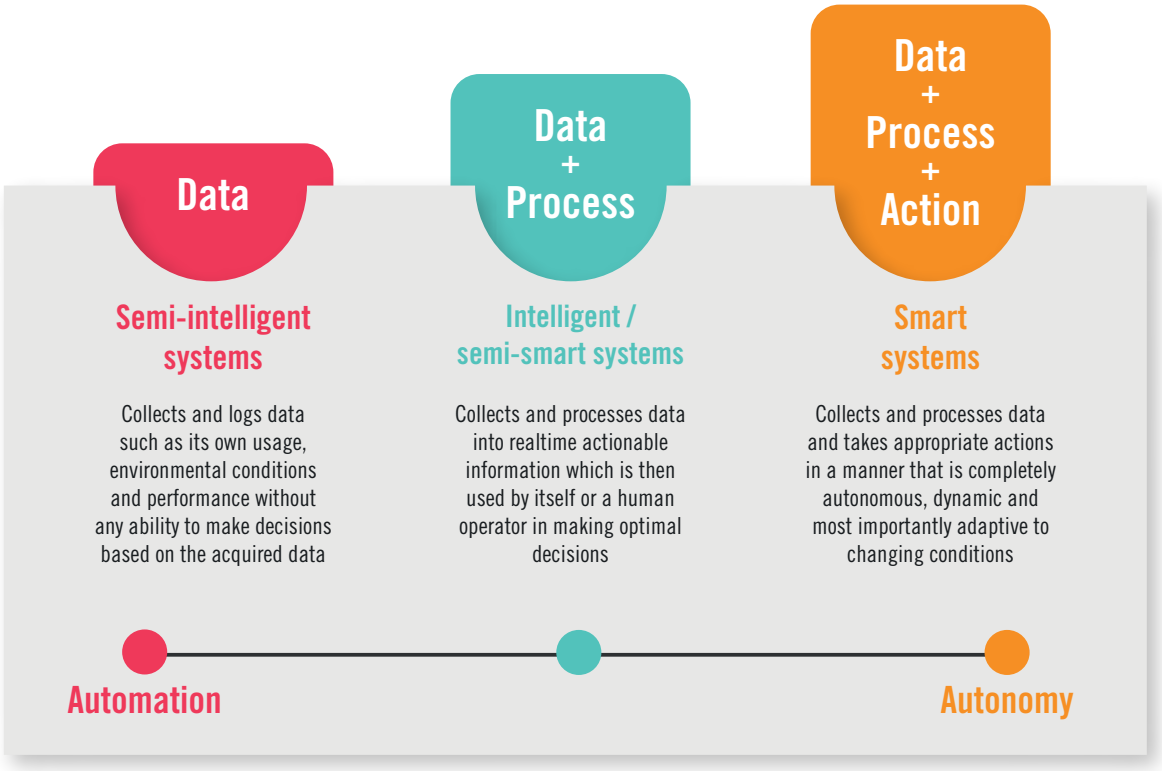

FIGURE 1: Adapted from levels of smart infrastructure by the Royal Academy of Engineering

It probably goes without saying that wherever you are on the automation to autonomy spectrum, a complex mix of advanced technology is required at each and every point. There is plenty to be gained from understanding the necessary sensor technologies, the AI algorithms, the simulation techniques to speed machine learning, the software and firmware and the sophisticated digital security required. We'll explore all these in this report, as we spell out the importance of identifying the right technology bundle to meet individual automation challenges.

In the early stages of automation planning, the focus should remain resolutely on the challenge at hand and the practical operational and efficiency gains that are to be had. Often, innovators quickly come to the realisation that full autonomy is not appropriate. There are sometimes exceptions to that rule of thumb. Full autonomy, for example, can sometimes be well suited to a warehouse, which is a well-controlled, well-connected environment. It is much more challenging to create that level of autonomy in an unstructured environment such as a building site, theme park or airport.

Nevertheless, more limited levels of automation can still have game-changing operational impact. Consider, for example, how onboard intelligence can help human operators deliver better results much more quickly (at the data plus process stage). Bulldozers with precise grade levelling, excavators that know precisely how deep to dig, tractor ploughs benefiting from precise mapping. These are big gains.

A couple of further points about your ambition. The first concerns investment. Although it might appear a tempting option, it can be a false economy to be constrained by off-the-shelf technology. Humans are endlessly adaptable, but we can't expect machines to be equally flexible. Your unique needs demand a unique solution that matches your specifications exactly. The second point is to pay close attention to value creation and your new business model. Just because you collect data doesn't mean that you automatically have the insight necessary to pave your route to revenue.

Once again, this links to the need for the sort of bespoke solutions that can deliver a return on R&D investments geared to your sector and disruptive business model. You've no doubt heard plenty of talk around the Fourth Industrial Revolution, Industry 4.0 and Industrial IoT. Much of it is focused on data, data, data. That's all very well, of course, but data although necessary is not the end in itself. Data without insight adds no value, but success will come for those who cherish insight, and react accordingly. This is the real key to putting distance between you and your competitors.

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3 INDUSTRY INSIGHT – THREE STAGES OF AUTOMATION ADOPTION

In this section we are going to explore three stages of adoption: emerging, maturing and advanced. In each case we have chosen indicative industries, but there are of course many more examples for each. As for our definitions, emerging relates to an industry still in the relatively early stages of applying such solutions. Maturing is where the sector has developed a number of proven products, but with plenty of room for further innovation. At the advanced stage, the sector has developed successful technologies and can clearly point to a number of significant benefits that have transformed their business model and market.

3.1 STAGE ONE – EMERGING

SMART INFRASTRUCTURE SECTOR

Smart infrastructure, by which we mean intelligent road, rail and transportation infrastructure and traffic solutions in and between cities, is just starting out on its journey of digitisation and automation. Construction, a crucial part of the mix of course, has some of the lowest rates of digital and automation adoption, and has been stuck in a cycle of low productivity and low profitability for decades.[1]

Significant economic stimulus would offer the opportunity to break this cycle, in the shape of considered investment in an automation to autonomy pathway that links the digital and physical worlds. The pathway should dictate the prioritisation of the assets to be constructed. For example, the catalyst for smart road development will be the increasing prevalence of autonomous vehicles. There will be a pressing demand for the road infrastructure to deliver information that is not accessible on the vehicle itself.

Surely then, there is an opportunity for infrastructure developers and operators to add significantly to their value?

On the surface yes, but the industry is characterised by a complex ecosystem of suppliers, something that is common across most of the smart infrastructure space. There are real challenges to making sure that the areas of the value chain that require significant investment in automation are also those that benefit in the long term from that investment.

The potential for gains are significant. Recent McKinsey reports estimated that digital transformation can result in productivity gains of 14 to 15 percent and cost reductions of 4 to 6 percent.[1] [2] The pathway to those gains, however, is often unclear. Anyone entering this space is looking at a vast sea of possibilities and might very probably have had a number of unsuccessful attempts in the past. Working out what the best first steps on the roadmap for development should be – amongst all of the potential options – is a challenge. This is why experience of identifying the most effective route is so invaluable.

Ambition is also important. The future of smart infrastructure is big picture stuff and demands broad, bold thinking. The desire for success must transcend any single-point solution. A number of steps – like getting all information into a single data lake – are important, but to really benefit from the power of digitisation and automation, system-wide thinking is essential. The development should be built on technology of course, but it is also about people and processes. Without these elements working together seamlessly, any isolated initiative is doomed to have minimal impact or not scale successfully. Pockets of excellence usually exist in companies setting out to innovate in this space, but the really successful ones will find a way to nurture that excellence and link it together powerfully.

Identifying short, medium and long-term value opportunities and placing them within an overarching vision – a common operating picture – is key to successful engagement and planning. Immediately, crucial questions can be addressed. What technologies exist to support the opportunities? What might need to be developed and on what timescales? Creating a strong vision to motivate your organisation and give clarity on why actions are being taken is also vital. It is a springboard to actions that deliver an immediate tangible benefit. In other words, the first firm and irrevocable steps on the journey of automation to autonomy. Smart infrastructure is an emerging and viable industry in which to make this happen.

3.2 STAGE TWO – MATURING

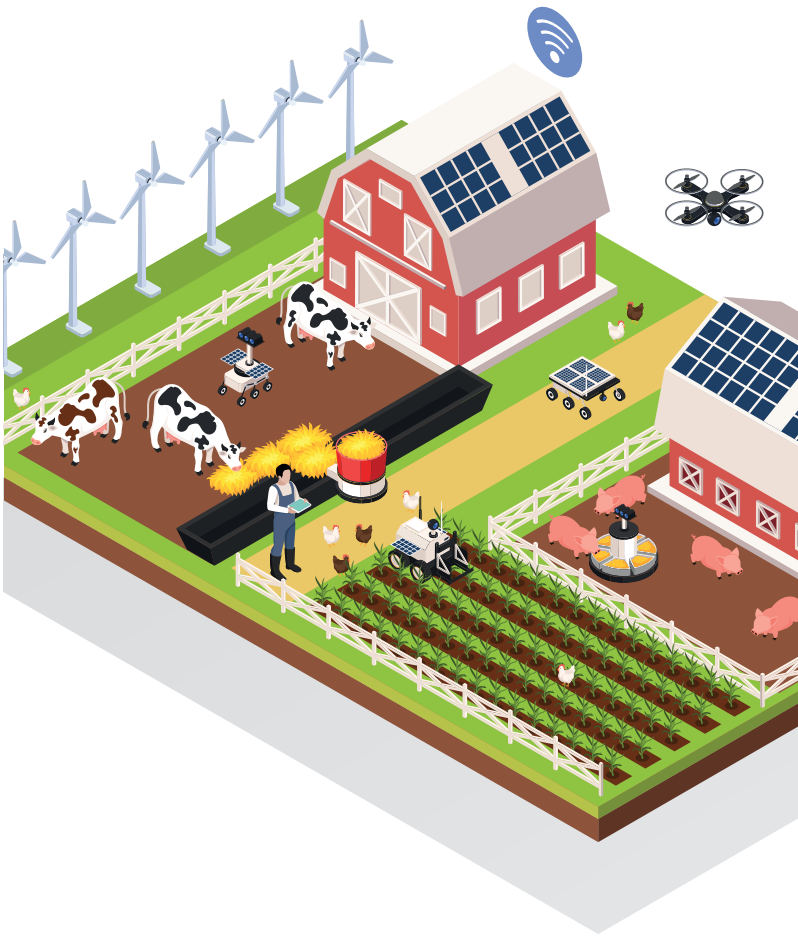
AGRITECH SECTOR

Overall, agritech automation is an area that is rapidly maturing, but there remains plenty of scope for further development. Intelligent automation and closed loop control – where devices automatically regulate a process without human interaction – are widespread. Examples include self-levelling spray booms and 'see and spray' technology that can differentiate between cultivated plants and weeds.

On the whole, agritech equipment vendors are adept at developing devices when the signal emanates from a traditional source, such as strain gauges or torque measurement devices. The story is slightly different when it comes to signals from less traditional sources like still images or video. This is still a developing area which requires more sophisticated process and interpretation intelligence. It explains why robotic fruit pickers are still very much at the prototype stage. The ability of the machine to know precisely 'what good looks like' is the next exciting stage of intelligent implement development.

That said, agritech is nothing short of a world leader in autonomous machines. The pioneering US machinery corporation John Deere has marketed self-steering combine harvesters for more than a decade. Elsewhere in the industry, planting machinery guided by real time kinematics GPS systems is accurate to one to two inches. Here, an operator only needs to intervene when dusty or wet conditions, or perhaps a tricky sun angle, cause problems.

Today's pressing challenge, and indeed opportunity, is to expand the range of use cases that autonomous vehicles and machinery is comfortable with. The key to unlocking further adoption is data, but of course the seasonal nature of agriculture means that obtaining this vital resource is very time consuming. To overcome this, an increasing number of innovators are moving to simulated environments to accelerate development and reduce R&D costs. Simulated environments lessen the need for collection of millions of hours of real-world data, through the ability to allow for synthetic data to be used to assess and refine autonomous equipment performance. Recently adopted by the automotive industry in an effort to reduce the huge cost of developing autonomous cars, simulation environments are now being adapted for use in off highway environments like agriculture, construction and mining. You can read more about this subject on page 12.



"an increasing number of innovators are moving to simulated environments to accelerate development and reduce R&D costs."

3.3 STAGE THREE – ADVANCED

LOGISTICS & RETAIL SECTOR

This sector is well into its journey to greater digitalisation and automation. The arc of innovation is widely documented here, with many use cases and numerous examples of companies making massive strides to transform their business model – and leapfrog their competitors. Some have developed breakthrough communication systems to enable swarms of robots in highly automated facilities. Amazon's vast warehouse operations are a good example, where robotic systems have been put in place to supercharge its order fulfilment process and make same-day delivery a widespread reality.

Even before the pandemic, retailers were under pressure to keep up with rapidly evolving supply chains and customer habits. Not only have payment methods and support services changed, but inventory and logistics functions also continue to shift. These developments are encouraging both brick-and-mortar and e-commerce companies to look to artificial intelligence and robotics in retail.

From supermarkets and consumer electronics to clothes and pharmaceuticals, all retail sectors must continue to drive innovation to remain competitive. Both online and physical stores are continually searching to improve efficiency, customer satisfaction and employee retention. Amazon, along with fellow retail giants like Walmart, are using their robots in warehouses and stores for all sorts of functions, including inventory scanning, materials handling and even cleaning. To be useful and effective, automated guided vehicles (AGVs) and autonomous mobile robots (AMRs) require operating systems and data collection and analysis tools that are robust and compatible with existing retail systems.

In our view, autonomous service and delivery robots are not just there to better serve customers, they are there to save retailers from possible demise. Not so much a game-changer as a game-saver. The sector is advanced in terms of automation, but challenges to further development remain. A big upcoming need, for example, is a multi-vendor, multi-site open-orchestration platform running different autonomous systems in a warehouse. Wireless communication, digital security, interoperability will all be key enablers for this. (See the following section 4 for more details.) Another big question is how shipment companies can reduce shipping times and cost. Large operators have anything from 20 to 40 manual touchpoints from shopping cart to the customer's door. Data aggregation and sensor fusion will be among the enablers here.

Some industry analysts have predicted that robotics in will be instrumental in more than three-quarters of retail logistics operations, with McKinsey making a rather bold estimate that autonomous vehicles will make up 85% of deliveries by 2025. That seems a stretch, but the trend is clear. For many logistics organisations, most of the cost is carried in providing last-mile service. This is driving an increased attention on super-efficient, real-time route planning and automated drones, vehicles and pods of all descriptions. A good example here is the FedEx 'same day bot' Roxo, which has passed legislative hurdles to operate as a last-mile delivery service in five US states. Further testing is under way to target more consumer use cases, from pizza delivery to groceries.

4 THE RIGHT TECHNOLOGY BUNDLE FOR YOUR AMBITIONS

Automation to autonomy is always a unique journey. Each organisation will embark and jump off at a different point, depending on the level and exact nature of corporate ambition, as well as the level of investment ambition. There are multiple roads to follow, influenced by the overall goal that is to be achieved. As a tech agnostic organisation with a multidisciplinary breadth of expertise, we invest a lot of time working with our clients to guide them through a complex and ever evolving technological maze.

Your ideal package would reflect this and would almost certainly include elements from some particularly effective approaches, techniques and technologies. Here is an overview of some of the most potent components of successful automation.

4.1 DATA AGGREGATION FOR INSIGHT

As we've made clear already, data is nothing without insight. New techniques are emerging to ensure that data that is derived from sensors can be interpreted rapidly and acted upon locally. Imagine, for example, an autonomous agricultural machine operating in the field. It can't rely on intelligent decisions being made in the cloud – the latency and delayed data processing involved as well as connectivity challenges would negate efficient operation. But if the intelligent computation power, in other words the AI processing capability, is situated on the device itself, the data can be processed immediately, and the action can happen straightway.

This 'AI at the edge' approach is well illustrated by Fafaza, a breakthrough crop spraying concept developed here at Cambridge Consultants. It performs both plant recognitions and precise, individualised treatment in the field, in real time. The system comprises off-the-shelf components and an AI compute platform costing less than $100. A low-cost camera identifies the target by texture, and machine vision probabilistic programming tracks the target and determines where to aim and when to fire. Everything is identified, classified and applied in real time, at the speed of the tractor. This is the power and cost-effectiveness of edge AI.

Another good example from the Cambridge Consultants stable is a fruit-picking robot that tackles the complex picking and sorting tasks involving irregular organic items. Unlike with repetitive production line tasks, fruit-picking robots must be able to work around people, cope with irregular items, and adapt to a changing environment. Designing a robot that is able to it requires many tasks to be performed – from recognising the correct objects and calculating what order to

pick them in, to planning the grip, and the lifting and placing of the items. The solution comes in the form of world-class industrial sensing and control that combines high-powered image-processing algorithms with low-cost sensors and commodity hardware to allow 'soft' control of robots when the task is not rigidly defined.

4.2 SIMULATED ENVIRONMENTS FOR ACCELERATED DEVELOPMENT

Developments shaped around automation and autonomy rely on inherent intelligence from AI, machine learning and deep learning. They, in turn, depend on feeding in vast volumes of real-world data. But the task of generating it is time consuming and extremely expensive. It is for this reason that innovators are turning to synthetic data and simulation to drastically reduce the cost and timescales of development.

Let's imagine a delicate and precise robotic task – picking strawberries in a field, say. It would be prohibitively slow and expensive to train the robot exclusively in real life conditions. But complementing a certain amount of in-field training with synthetic data allows the machine to be tested in thousands-upon-thousands of simulations. The development proceeds more rapidly and the innovator gets to market before their competitors. When it comes to simulated environments, an interesting example can be seen in the automotive industry, where mature gaming engine platforms such as Unity and Unreal have been used to speed the development of algorithms and scene understanding on the road to autonomous driving.

The algorithms can be rigorously tested for obstacle detection, location precision and path planning without the need for expensive hardware and time-consuming real-world trials. Further, simulation environments allow for testing or response to rare or usual operating conditions. These 'edge cases' are very difficult to obtain in the real world because they require specific combinations of weather and obstacles. Simulation environments offer the opportunity to recreate those dusty, low sunlight, wintry conditions that could overwise lead to a significant failure and determine interesting combinations of sensor suites to cope with such eventualities.

4.3 SENSOR FUSION

Essentially, sensor fusion is the process of combining data from disparate sensor sources to provide insight that is more certain than it would have been from the individual sources. To illustrate its efficacy, let's return to the autonomous driving. Currently, reliable perception solutions are extremely expensive. This makes it tough for industry players trying to establish a viable industry model to push autonomy behind the luxury segment and into mid-range vehicles. Creating an accurate depth picture is one of the biggest obstacles.

The problem is exacerbated by one of our key themes – the barrier to innovation caused by the need to capture massive amounts of real-world data to train the system. In response to the challenge, a team here at Cambridge Consultants developed a concept called EnfuseNet,[3] which fuses data from extremely low-cost sensors and cameras to generate high-resolution depth data, the reference point that autonomous systems need. The system was created within a modular and flexible AV simulation environment which enables faster and cheaper development of the model. Consequently, the complexity of sensor fusion calibration, real-world interference, noise and other effects can be dealt with at the earliest stages.

4.4 COMMUNICATIONS TECHNOLOGY

As this paper is illustrating, the post-pandemic world is witnessing an accelerated democratisation of access to AI techniques, enabled by faster and cheaper compute, better data and significant advances in machine learning techniques. AI and edge computing have reached a level of maturity needed for widespread and effective implementation which is being boosted by a third key component – wireless connectivity.

Communications technology, in the form of wireless networks, satellite communication networks, cellular networks and many more, continue to transform our personal and business lives. The availability of radio spectrum for 5G is opening new opportunities across the world for enterprises to own and operate their own private networks, for example Citizens Band Radio Service (CBRS) in the United States. Ambitious enterprises, for example, are seizing on the advantages of newly released spectrum that allows them to create private 5G networks. This new connectivity opens the way to a host of new industrial use cases – not just in relatively easily controlled environments like warehouses but in outdoor areas such as farmyards and travel hubs. Let's take a busy shipping port as an example. Previously, without usage data provided by wireless connectivity, maintenance of a crane would follow a fixed schedule or happen when it breaks down. But streaming data enables the operator to predict the breakdown, scheduling maintenance accordingly. Both the use of the equipment and general efficiency are improved significantly.

4.5 DIGITAL SECURITY

The technologies concerned with digital security are taking an ever more influential role in the automation to autonomy journey. It is clear that higher levels of connectivity and automation bring with them increased risk from hostile players. Such systems are likely to be a target from not just criminals but also nation states. This is true across sectors and even in agriculture, which is part of the Critical National Infrastructure, as designated by the CPNI (Centre for the Protection of National Infrastructure) in the UK.

Our advice is always to build security in from the start of any automation or autonomy based development. There are many examples of solutions developed for a particular industry then being used in another, with security compromised as a result. It is important to work from the ground up, with a focus on robust system design. Formal design processes will ensure that the risks and vulnerabilities of the product or service are addressed. This means establishing the security requirements to set the overall strategy, define the security architecture and system design, and test to verify regulatory and legal compliance. A final word here: threats in the far future also need to be considered. At Cambridge Consultants, our experts are developing solutions to meet the quantum computing challenge. The coming quantum revolution will bring a magnitude of gains over today's classical computing approach, as well as greater security risks. Work is already under way to understand the challenges and develop new, secure architectures to protect assets that will be deployed for decade-long timeframes, such as infrastructure.

5 CONCLUSION

There are several clear strands that inform effective automated and autonomous systems. Moving successfully from data capture to deep insight will not only reduce development time and costs, but it offers up the potential for new revenue streams. Intelligent automation will improve efficiencies for you in manufacturing and operations and also for your customers by optimising their 'jobs to be done', saving time and resources. World-first autonomy will deliver product and service differentiation capable of putting clear water between you and your competitors, increasing market share in the process. At the heart of successful implementation sits a bundle of technology options:

DATA AGGREGATION FOR INSIGHT – new techniques are emerging to ensure that data that is derived from sensors can be interpreted rapidly and acted upon locally

SIMULATED ENVIRONMENTS FOR ACCELERATED DEVELOPMENT – synthetic data and simulation is now able to drastically reduce the cost and timescales of development

SENSOR FUSION – the game-changing ability to combine data from disparate sensor sources to provide insight that is more certain than it would have been from the individual sources

COMMUNICATIONS TECHNOLOGY – wireless networks, satellite communication networks, cellular networks and many more, are ready to help transform industry

DIGITAL SECURITY – a vital component of a successful automation strategy, to combat the heightened risk

The secret is to pursue your ambitions with the optimal mix of technology tailored to your unique needs, and with a partner capable of providing clear, impartial and objective advice. The Cambridge Consultants team has a proven record of success in automation and autonomy – and would be delighted to continue the conversation.

WHY US?

We can draw on deep expertise to offer a uniquely broad response to your automation to autonomy challenge. Our skills and knowledge combine with real-world application experience that has been earned by multidisciplinary in-house teams.

Above all, we love to create collaborative partnerships with our clients, and are proud of our record of developing and maintaining long-lasting, mutually beneficial relationships. The team is ready to help get you where you want to be – with reduced development risk, time and cost.

Learn more:
www.cambridgeconsultants.com/automation-autonomy

Please get in touch to discuss your ambitions

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About Cambridge Consultants

Cambridge Consultants has an exceptional combination of people, processes, facilities and track record. Brought together, this enables innovative product and services development and insightful technology consulting. We work with companies globally to help them manage the business impact of the changing technology landscape.

We're not content to deliver business strategy based on target specifications, published reports or hype. We pride ourselves on creating real value for clients by combining commercial insight with engineering rigor. We work with some of the world's largest blue-chip companies as well as with innovative start-ups that want to change the status quo fast.

With a team of more than 900 staff in Cambridge (UK), Boston, San Francisco and Seattle (USA), Singapore and Tokyo, we have all the in-house skills needed to help you – from creating innovative concepts right the way through to taking your product into manufacturing. Most of our projects deliver prototype hardware or software and trial production batches. Equally, our technology strategy consultants can help you to optimize your product portfolio and technology roadmap, investigate new opportunities or refine your operations.

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