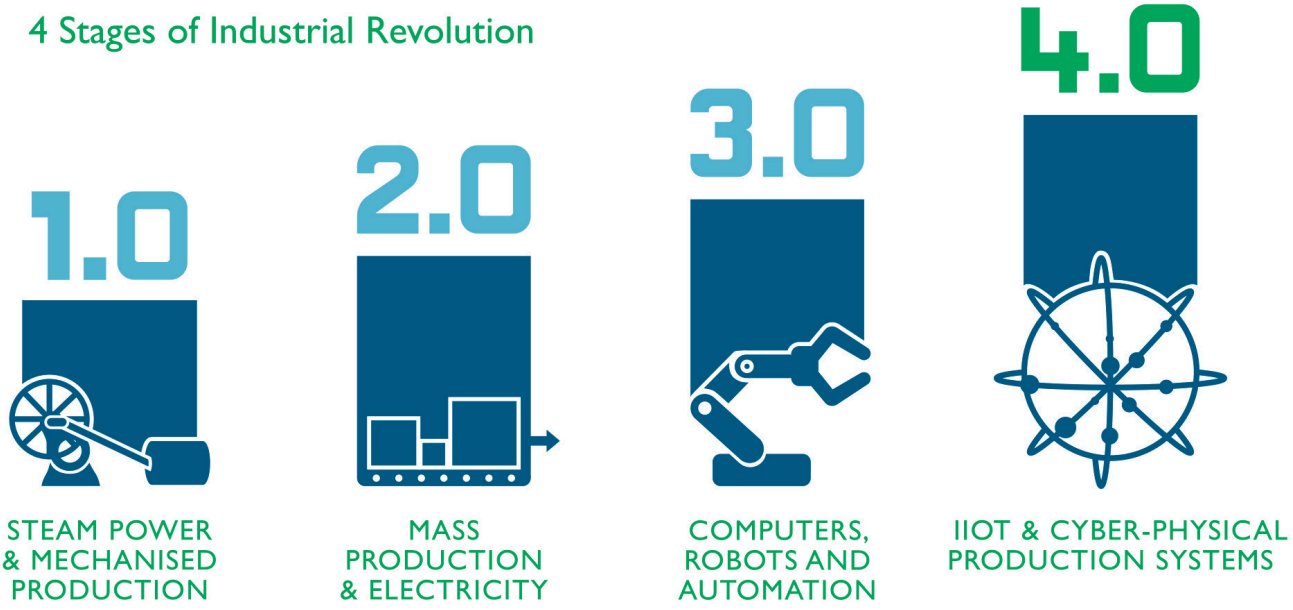
Shaping Industry 4.0 in coding and marking

The fourth industrial revolution

We're in the midst of an industrial revolution. Industry 4.0 is an umbrella term to cover a fusion of technological advances that are transforming the world's manufacturing and production industries. This paper will summarise what Industry 4.0 is and the benefits it will bring, identify technologies at its core and present how Domino is helping to shape the revolution.

Let's look at what Industry 4.0 actually means beyond the buzzwords. It means that every individual machine, system and set of processes across the factory and throughout the enterprise will be integrated, and connected to the internet. It's as much an evolution of existing automated systems (like assembly line robots or packaging equipment) as it is a revolution. In some areas it's easy to blur the lines between 3.0 and 4.0, in other areas new technologies, such as 3D printing and augmented reality, will radically change the way we do things.

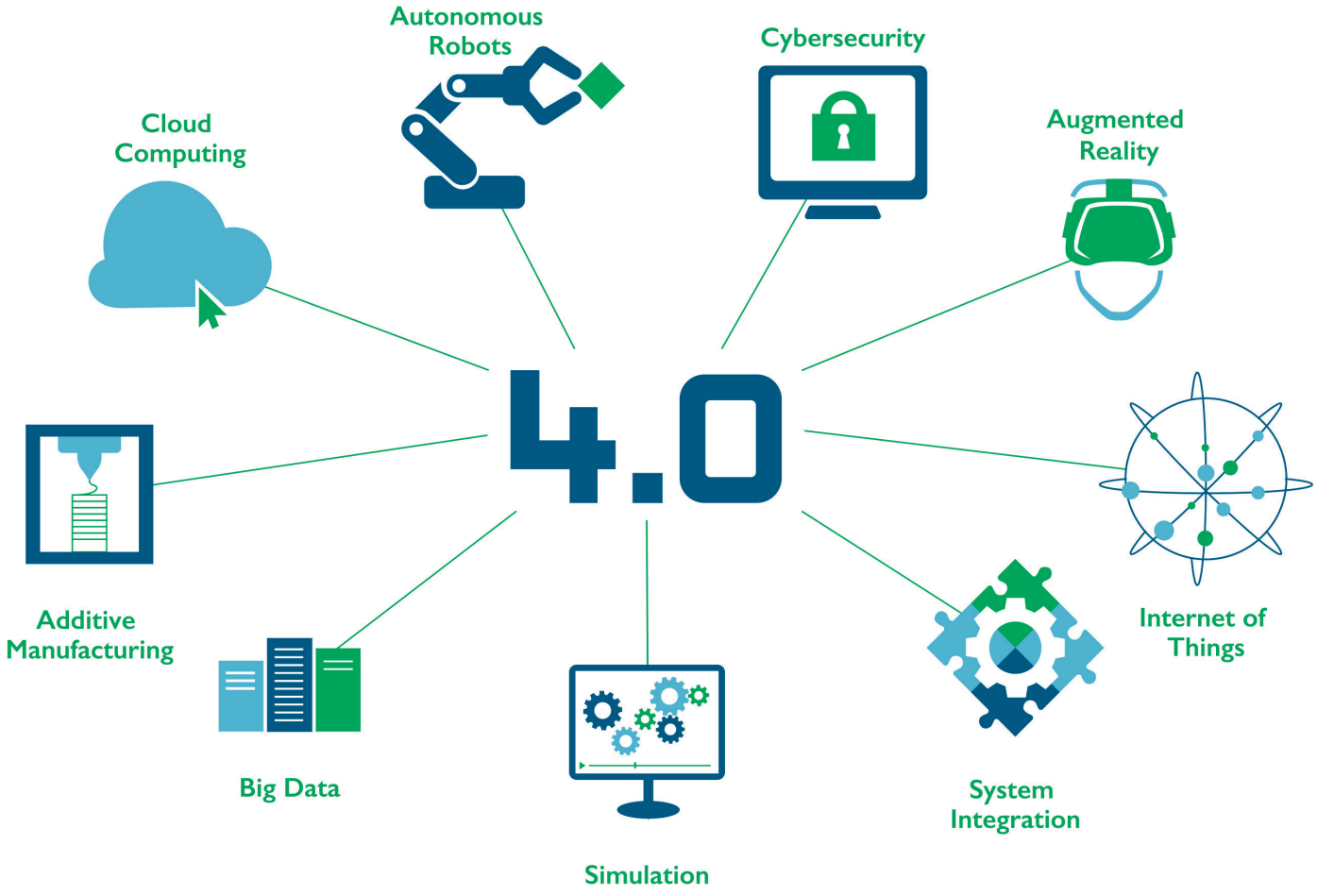


This unprecedented level of connectivity allows information to be captured at every point on the production process and throughout the supply chain. The resulting OEE data can then be analysed and managed to make every manufacturing sequence as fast and accurate as possible.

Simply put, the Holy Grail of maximum efficiency could be realised with Industry 4.0.

To understand how Domino is helping to drive Industry 4.0, you need to know about a handful of core concepts: horizontal and vertical system integration, big data, cloud computing and the Industrial Internet of Things (IIoT).

Key Industry 4.0 technologies:



Under Industry 4.0, equipment and systems at every level of production are integrated and all the data gathered from the factory floor is imported into the "cloud". This "cloud" is an internet-based repository where information can be stored and accessed from any location. In other words, the workflow, maintenance and management of every machine can now be done remotely.

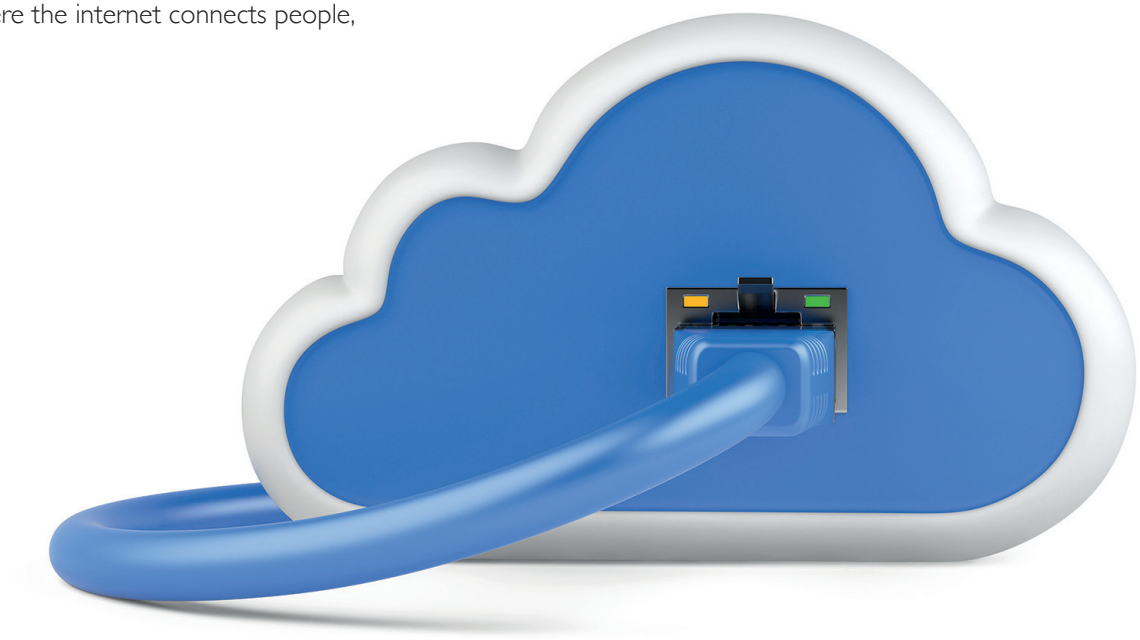
But, how can you monitor and analyse a production line's processes?

This is where the "Industrial Internet of Things (IIoT)" comes in. First, let's take a step back and explain the "Internet of Things (IoT)". The IoT is a simpler version of the IIoT. Under the IoT, devices are connected over the internet, letting them talk to us, applications, and each other. The IoT is incorporated into a range of consumer devices. A typical IoT example is a wrist-worn activity tracker, like the Fitbit. These devices contain computing power and software to monitor and analyse your activity before relaying this information through the internet to a dedicated mobile app. Such devices are collectively referred to as "Cyber-Physical Systems (CPS)".

The IoT is a network of physical objects embedded with internet-connected technology to communicate and cooperate both with each other and with humans in real time, via the cloud. The IIoT supersizes this concept. It's a network of networks, where the internet connects people, processes and assets, enabling a new way to operate and optimise factories. Previously disparate physical systems are now connected at every stage of the production process. Devices, equipment, units, plant areas, plants, sites and every level of the enterprise are now connected to each other.

A core component of Industry 4.0 is the adoption of universal communication standard protocols to enable easier equipment integration and a solution to "islands of automation" in a large factory. Multiple automated manufacturing processes often evolve in silos, but the IIoT demands that these systems communicate together and with plant-wide control systems. Communication standards provide the patterns for the bridges that connect all parts of the factory together, and collectively to the internet – from devices and production lines, to the integration of printers into Original Equipment Manufacturer (OEM) machines.

Standards offer further benefits to manufacturers beyond 'plug and play' (plug and play devices work with a computer system as soon as they are connected). They present a consistent and secure approach to collecting and passing data through the various systems for efficiency analysis (overall equipment effectiveness (OEE) indicators, cost transparency), track and trace, and monitoring production processes and product quality.



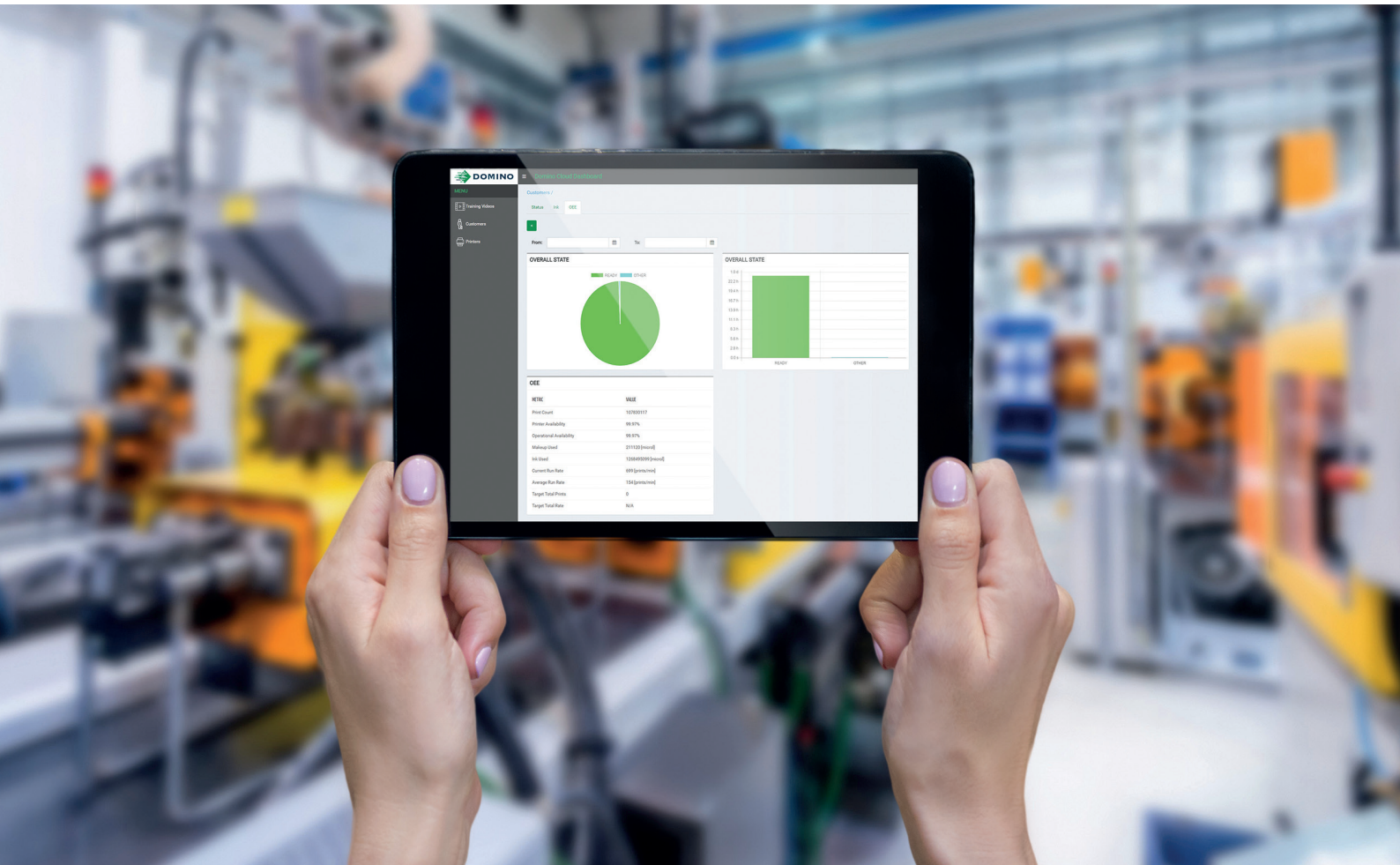
Let's look into this concept of horizontal and vertical system integration a little further. In a manufacturing environment, we have more complex Cyber-Physical Production Systems (CPPS). These pieces of software-enhanced kit feature the computing power of a CPS, but they also contain embedded actuators and sensors to automate decisions and self-diagnose based on the current operating environment.

The integration of monitoring equipment means the factory and all its equipment will know its state, history, capacity, maintenance plans, possible configurations and setups, and so on. This highlights an important difference: a CPS works independently to communicate and store information in the cloud, but a CPPS works to form a network of self-diagnosing and self-maintaining systems in the cloud.

The CPPS network and its processes (that are usually managed internally) can now be accessed and managed from anywhere in the world. This will have a massive impact on the way manufacturing and production systems currently function. Centralised and offline systems that are not inter-connected will evolve into a web of connected systems.

This will free a tsunami of data. But, instead of drowning in data, the technologies (such as cloud computing and the IIoT) that sit at Industry 4.0's heart allow this huge volume of data, known as "Big Data", to be used effectively through dedicated data analysis. This data liberation will evolve traditional factories into "smart factories" where cyber-physical production systems monitor physical processes and make decentralised decisions.

For example, Domino's **i-Techx** platform collects a vast array of data on printer operation - from ink and makeup levels, to wear and tear on components. This data is sent to the Domino Cloud where it can be accessed by a helpdesk team to remotely monitor printers, diagnose faults and spot potential future issues - often before our customers know something's wrong. Industry 4.0 technologies like the cloud and IIoT are revolutionising our customer support services, and greatly increase the operating efficiency of our printers.



In the future, printers could be automatically controlled using artificial intelligence (AI) in the cloud to resolve any issues and optimise their efficiency. Whether the automatic operation of printers - or indeed any production-critical equipment – without any human intervention is desirable in a factory setting is yet to be seen.

As more systems are integrated, the greater the benefit for manufacturers. For example, Domino's R&D labs are using the real-life (anonymous) data collected in the Domino Cloud to advance our printers and consumables. By analysing how the inks normally used in a particular factory perform we can start to suggest the best possible solvent-ink ratio, and recommend alternative inks for the environment.

The variations to the processes and resulting products are limitless - and so are the possibilities Industry 4.0 presents to the manufacturing and production industries.

Benefits of Industry 4.0

Increased performance and profitability

FMCG plants are continually looking for new ways of optimising manufacturing conditions so they can increase production at the lowest possible cost.

Industry 4.0 will allow factories to continuously monitor information about equipment utilisation and cost structures, and through the integration of decentralised systems able to self-diagnose and resolve issues in order to streamline processes and maximise profits.

With pressure to manufacture a higher quantity and quality of goods using less energy and raw materials, the implementation of systems and processes that promote sustainability, flexibility and efficiency is now the only viable option to meet such high demands.

Customer empowerment

Industry 4.0 will give customers greater control over the products they buy by enabling manufacturers to build efficient systems for mass customisation and 'batches of one'.

Intelligent automated systems enable tailored products to be manufactured at great speed and with great agility, removing the large costs and time delays involved with manual production changeovers. This gives customers opportunities to configure products to their exact requirements – for example, through a website that relays orders direct to the factory – without paying bespoke service costs.

Whether the factory in question produces personalised breakfast cereals, customised prosthetic limbs using a 3D printer or the item-level serialisation of pharmaceutical products, all this can be achieved at a lower cost and with relative ease.

Serialisation and unique product identification

Printing uniquely identifiable codes onto products, with data aggregated through primary and secondary packaging, enables the flow of goods from manufacturer to consumer to be better tracked. By scanning these codes, resellers and consumers can check that products are genuine, not subject to a recall, or beyond their shelf life. Any issues can be traced back through the supply chain to pinpoint the source and rectify it.

This is particularly important in the life sciences, food and beverage industries, where legislation is being put in place. For example, Unique Device Identification for medical devices in the United States and the Falsified Medicines Directive for pharmaceutical products in the European Union.

Increased supply chain visibility brings further benefits to manufacturers, such as better inventory and materials management and improved handling of recalls.

Applying smartphone-readable codes to products also opens up a host of new ways for brands to strengthen customer loyalty and increase sales through personalised product experiences, and gives consumers access to more information on what they're buying.

Safer products, manufacturing insight, and consumer interaction through mobile phones is all made possible by Industry 4.0 technologies such as the IoT, cloud and big data.

Servitisation

Servitisation is a term used to describe an organisational shift from selling products to selling an integrated product and service offering that delivers value in use. IoT connects products to customer service systems through the cloud. Machine data that's collected and analysed in the cloud enables faults to be identified and resolved remotely, and even anticipated. Reactive fixing becomes predictive maintenance.

This increased level of connectivity opens new opportunities for how products are sold, converging product and after care into a single service-centric offering. For example, instead of paying upfront to purchase a continuous inkjet (CIJ) printer, and then continuing to pay for refill inks and replacement parts, Domino could enable customers to simply pay per code. In this model, customers are buying printed codes from Domino, who in turn ensures the reliability, efficiency and uptime of the printing equipment it supplies – through its connection to the Domino Cloud.

An end to uncertainty

What will customers order and when? Which equipment requires maintenance and why? Where do you see wastage and errors on the production line? Industry 4.0 ends an era of uncertainty through the effective management and analysis of the data it creates. Forecasts and assumptions are replaced with a highly granular level of knowledge and insight.

Domino Printing captures data on operation, performance and consumable usage for each individual printer connected to the Domino Cloud. Alerts to faults and potential downtime-causing issues (e.g. wear and tear on components or low ink reservoirs) are sent via the Domino Cloud dashboard to our helpdesk for fast diagnosis and remote assistance - enabling Domino to proactively support customers, contacting them before they even know there's an issue.

This unprecedented data analysis will further increase productivity, allowing manufacturers to analyse the effectiveness of their products, systems and processes. It will give them insights into their manufacturing performance and customer behaviour to develop new products to match demand in real time.

The intangible is now tangible thanks to Industry 4.0.

Revolutionising coding and marking

Industry 4.0 is not an overnight revolution. Due to the breadth of changes, from both a cultural and technical standpoint, this transformation will require time to take effect. But this transformation is happening - and it's happening now across a range of industries. And our customers are eager to reap the rewards Industry 4.0 offers.

"Manufacturers aren't waiting for others to lead the way: significant numbers of businesses appear to have firmly-identified projects in mind, with equally firm plans to fund those projects over the next year to 18 months," according to the Industry 4.0 UK Readiness Report.

Domino is in the unique position to help customers take their first steps into Industry 4.0 by slowly introducing its concepts to the entire factory floor through our printers.

For example, our **i-Techx** printers could be used as a pilot project to establish proof of concept and demonstrate the business value of IIoT technology - preventing unplanned downtime and faster fault resolution through intelligent monitoring and diagnostics. Such early successes will help customers gain buy-in from the organisation to adopt further IIoT technology.

The following pages highlight a few examples of how Domino is shaping Industry 4.0 for maximum efficiency in coding and marking:

Example 1: Defeating downtime through proactive monitoring

Example 2: Empowering customers through the IIOT

Example 3: Eliminating recalls caused by operator error

Example 4: Seamless interoperability through standardisation

Example 5: Protecting consumers through serialisation

Example 1: Defeating downtime through proactive monitoring

Our customers want peace of mind that our printers will remain operational at all times, and Industry 4.0 is helping to realise this ambition.

The recently launched Ax-Series Continuous Inkjet (CIJ) printer uses an array of integrated sensors to automate system monitoring and send data to the Domino Cloud. And with the ability to connect to the Domino Cloud through 3G (as well as Ethernet and WiFi), an existing network isn't a prerequisite.

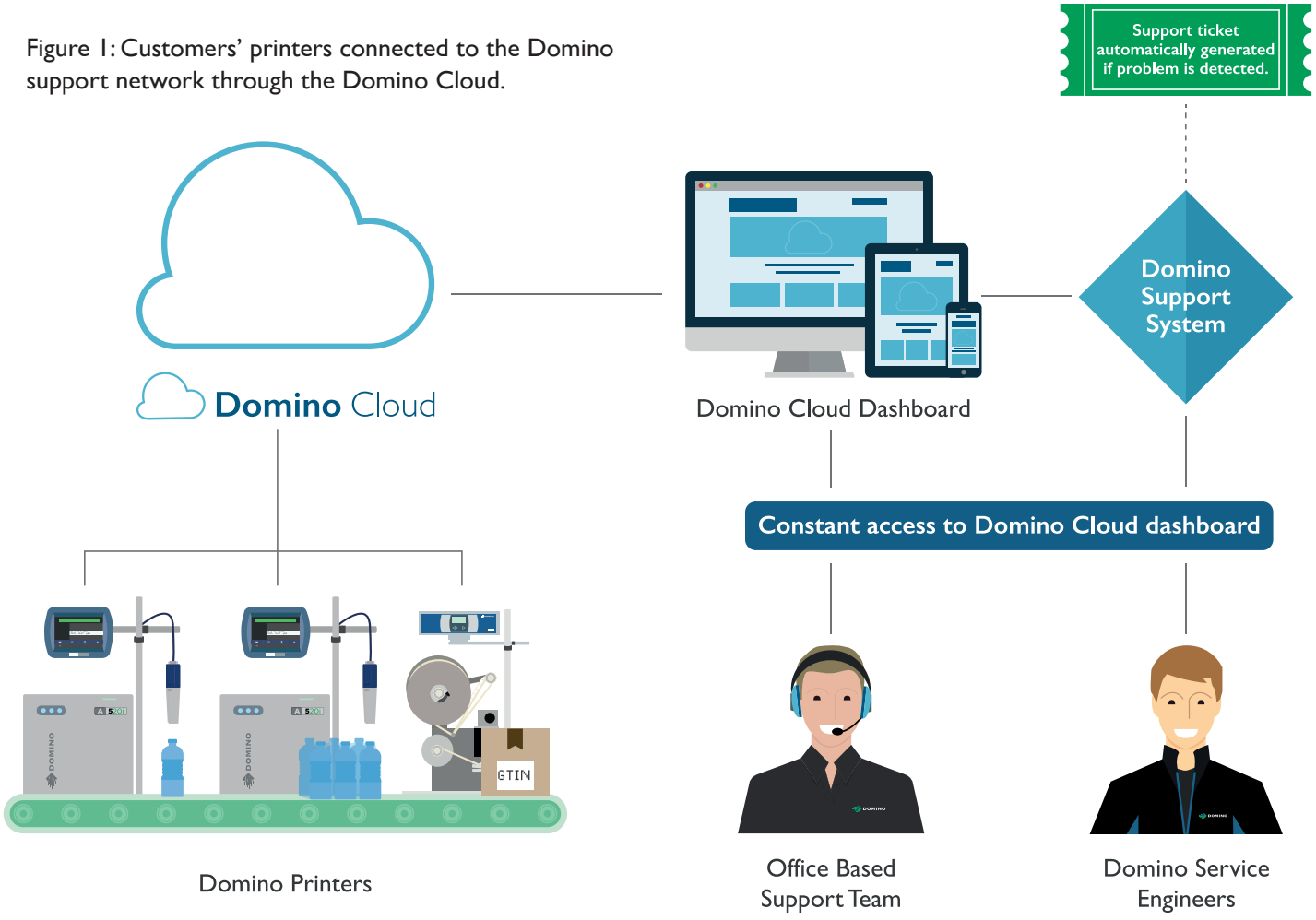
There are numerous customer benefits to this set up. Our Domino support team and our service engineers use the Domino Cloud dashboard to monitor printers and detect any reliability issues. This can be done remotely. There's no need for our engineers to go to a customer site to diagnose a fault.

If a fix is required, our engineers can turn up on site prepared with the knowledge and any spare parts they need. They can also guide our customers' engineers over the phone if they're equipped to service printers on site.

That's not all. The support teams and service engineers will automatically be alerted of any faults and potential issues with our printers via email and through the dashboard. This enables issues to be managed faster and resolutions sought before they impact the production line.

This proactive approach gives our printers the best chance to remain operational. If a fault does occur, the customer doesn't have to wait for an engineer to visit. This gives customers the most efficient and cost-effective solution to any issues that have, or could, arise. Remote management is a powerful weapon in our arsenal to defeat downtime.

Figure 1: Customers' printers connected to the Domino support network through the Domino Cloud.



Example 2: Empowering customers through the IIoT

It's not only our support teams and engineers that can monitor printers - customers get valuable insights into their printer operations at their fingertips.

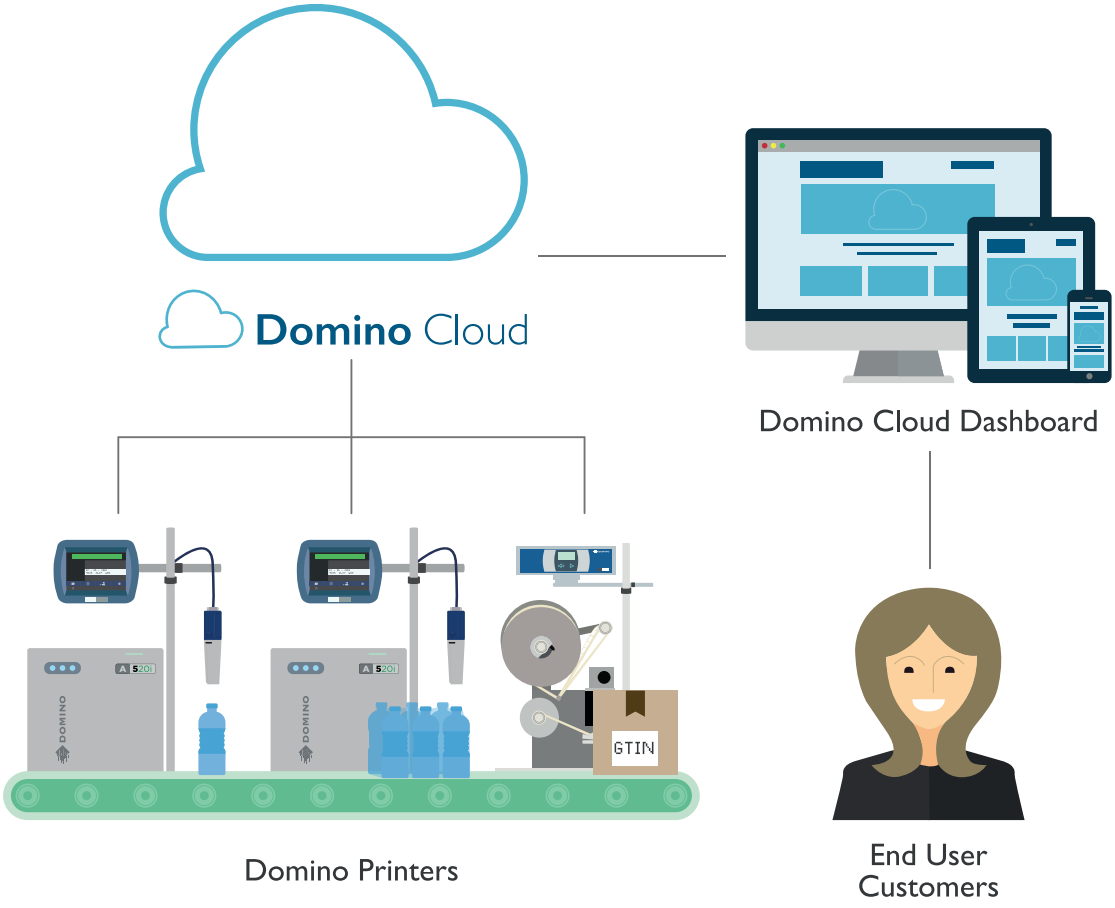
In this scenario, our end user customers get access to the Domino Cloud dashboard, which they can view on any device with a web browser. This has powerful implications for their printer management strategies.

The customer can check the status of their printers from any location, remotely diagnose faults, plan ahead for refills and reorders by watching ink levels and usage. They can also set email alerts if, for example, ink levels reach a dangerously low level - and can take action before downtime occurs. All without physically needing to be at the printer.

That's not all. By monitoring cleaning and equipment maintenance schedules, the longevity of the printers and their components is also increased.

It gets better. The customer doesn't just have access to this information for one printer, production line or plant. They can compare the performance across all lines, plants and sites, allowing them to take a global approach to optimising production efficiency. All this data can feed into OEE reporting. Using cloud connectivity, important information isn't just available - it can be effectively analysed to optimise every production line and bring the very best productivity to the customer.

Figure 2: Customers connected to their printers through the Domino Cloud.



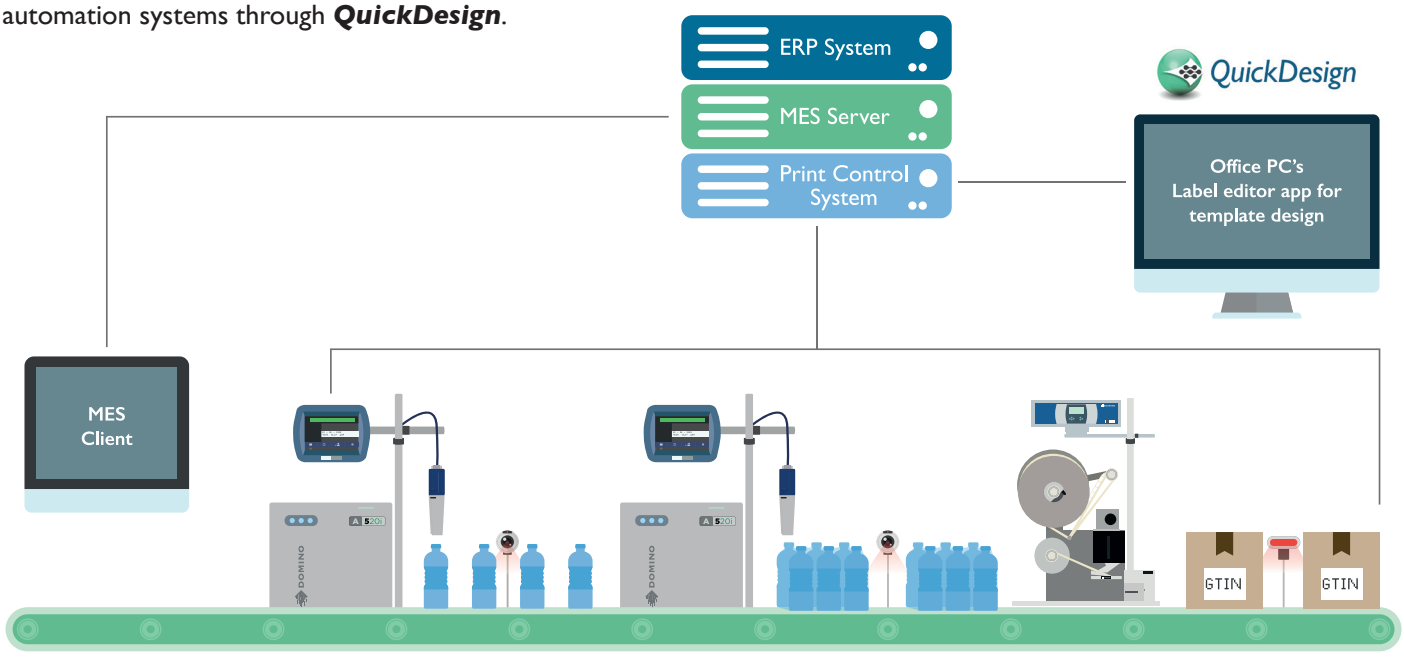
Example 3: Eliminating recalls caused by operator error

Incorrect information entered on printers by operators results in costly recalls and reworks for the customer. It's a major cause of unplanned production downtime. Integrating printers with factory automation systems, such as MES (Manufacturing Execution System) and ERP (Enterprise Resource Planning), enables labelling data to be coordinated automatically without the need for human input.

Domino printers are integrated with MES and ERP via Domino's ***QuickDesign*** software. During production, the MES fetches product data from the ERP system and sends it to ***QuickDesign***, which identifies the correct label template and loads this onto the printer along with the variable data automatically. Operators are still able to carry out essential tasks but this is managed through customised user interfaces (UI) on factory touch screens that restrict user input.

Switching from manually operating each printer to the centralised management and automated coordination of jobs, labels and data, removes the risk of human error and prevents coding and marking errors.

Figure 3: Domino printers integrated with factory automation systems through *QuickDesign*.



Example 4: Seamless interoperability through standardisation

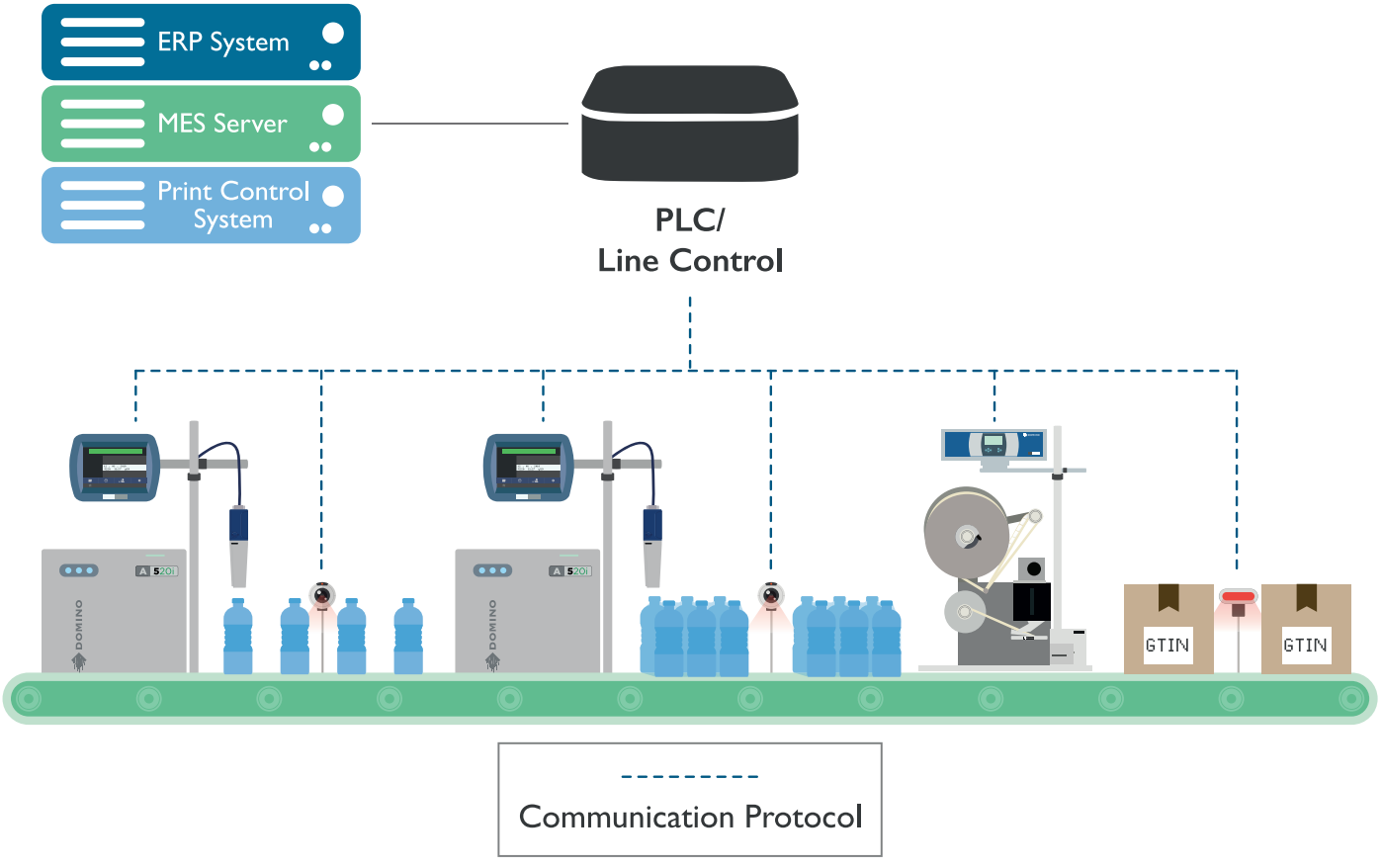
Communication standards enable the seamless transfer of data between equipment and factory systems to reduce setup, support and development costs. They provide a universal method to collect production information to measure the OEE of complete packaging lines, removing the risk of data inconsistency from control software interfacing between pieces of equipment.

If you imagine a production line in its entirety, data and instructions flow through a variety of equipment that are often supplied by different companies – devices like printers, check weighers, vision systems and PLCs, and whole packaging systems from OEMs. By adopting a common data language, setup times are reduced and there's no need to develop software to interface between equipment – reducing development time.

Weihenstephan Standards (WS) is a communication standard that is being adopted by many multinational corporations (MNCs) in the food and beverage industry. ***QuickDesign*** WS enables Domino printers to connect with other equipment and systems in a production environment using WS (as shown in the figure below).

This thinking could be extended to any communication standard, such as PackML (defining a common approach for programming and machine states for automated packaging machines) and OPC UA (a machine-to-machine communication standard for industrial automation developed by the OPC Foundation).

Figure 4: Domino printers integrated with factory equipment through industry standard communication protocols.



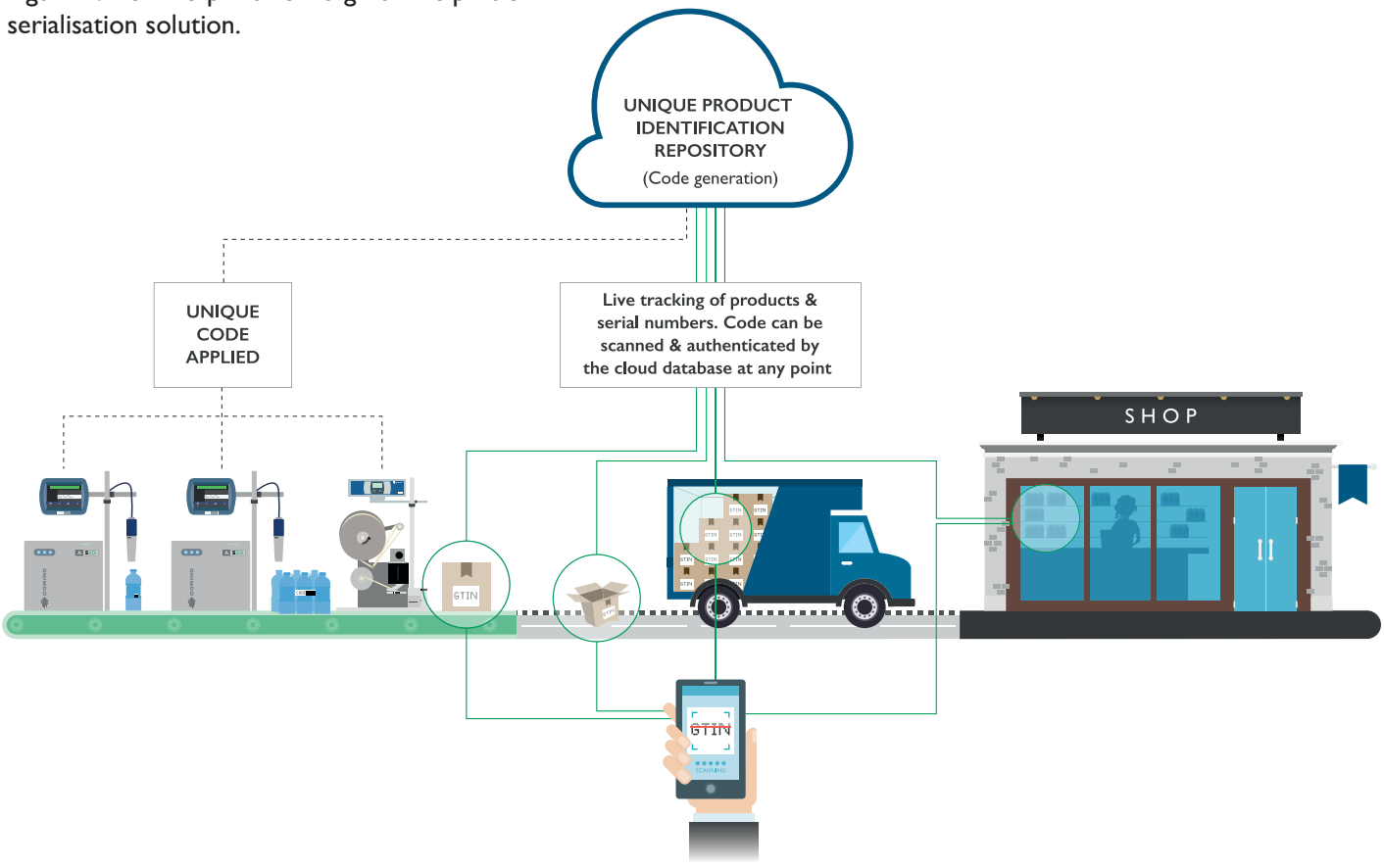
Example 5: Protecting consumers through serialisation

Domino has developed a number of solutions for the unique identification, aggregation, tracing and verification of products to meet the challenges of serialisation.

Our serialisation products generate encrypted, unique numbers, and enable multiple levels of aggregation and integration with Government databases, enterprise systems and contract manufacturing organisations (CMOs).

Online portals enable live tracking and authentication of products through the supply chain. If items are removed or changed during production, or damaged during transit, the associated serial numbers are decommissioned and the data in the central repository is updated. Scanning products at the point of purchase gives assurance to consumers and retailers. For example, pharmacies can validate medicines prior to dispense, and customers (via smart phone apps) can check food products are safe before they purchase them.

Figure 5: Domino printers integrated as part of a serialisation solution.



Conclusion

Industry 4.0 is not a just revolution but an evolution of technology, attitudes and techniques across every section of the world's manufacturing and production environments.

The benefits of the fourth Industrial Revolution are clear to see. From increased performance and profitability to customer empowerment to servitisation and serialisation, each advantage is working towards the ultimate goal for any production environment: maximum efficiency.

Domino is uniquely positioned to help our customers achieve that goal by steadily introducing Industry 4.0 concepts and innovations to our products. This brings additional and more specific benefits to the factory floor. Recalls from operator error are eliminated, standardisation enables seamless interoperability and proactive monitoring defeats printer downtime.

Industry 4.0 should be thought of as a journey rather than a single event, where improvements can be made to systems across the factory in manageable chunks. Products, technologies and new ways of doing things can be introduced bit by bit, eventually building up to a whole system optimised for maximum OEE.

Industry 4.0 is also a truly unique opportunity for both us and our customers to not just survive - but thrive as innovators and early adopters while the world's latest Industrial Revolution steadily marches on.

For more information, please see the Domino website: http://www.domino-printing.com

Glossary of terms

Additive manufacturing

Additive manufacturing uses 3D design data to deposit material in layers to produce a component. Also known as 3D printing, it is currently used to produce prototypes and individual parts. Under the connectivity of Industry 4.0, small batches of products could be produced as it enables the free flow of this 3D design data and automation of the print process.

Augmented reality

Augmented reality superimposes a computer-generated image on a user's real view of the world. It is still in its infancy, but it could be used in the manufacturing environment to, for example, help a worker repair a piece of machinery by relaying directions to them using augmented-reality glasses.

Autonomous robots

Robotics has long featured on the factory floor but, under Industry 4.0, these machines will eventually work side-by-side with and learn from human workers. Autonomous robots will, therefore, be able to tackle more complex assignments than those used in manufacturing today.

Big Data and analytics

Big Data refers to the huge data sets that result from the collection of information across the production line. For this data to be of any use and support real-time decision making, it must be comprehensively evaluated - and so big data and analytics go hand-in-hand.

Cloud computing

A network of remote servers hosted on the internet, which is used to store, manage and process data, rather than using a local server or personal computer.

Cyber-Physical System (CPS)

A CPS is a physical object embedded with software. This embedded software monitors and controls the physical processes of the physical object it inhabits.

Cyber-Physical Production System (CPPS)

Within a manufacturing environment, a CPS increases in complexity and scale to be a cyber-physical production system. A CPPS is software-enhanced machinery that also contains embedded sensors and actuators to self-diagnose and automate processes based on its current state.

Cybersecurity

Cybersecurity protects electronic data against criminal or unauthorised use. This is a top priority under Industry 4.0 as physical systems and processes could be attacked from any remote location once they are connected to the internet.

EtherNet/IP

Ethernet/IP (Ethernet Industrial Protocol) is a network communication standard for handling large amounts of data. Ethernet/IP is used with PCs, robots, production line devices and programmable logic controllers (PLCs). Development of the standard is managed by Open DeviceNet Vendor Association (ODVA).

Fieldbus

Fieldbus is a family of standardised industrial computer network protocols used for real-time distributed control. Its IEC 61158 standard is organised around eight different protocol sets called "types" including the PROFIBUS (Process Field Bus) communication standard in automation technology.

An example would be a distributed control system that is used on a manufacturing line. This control system would typically be comprised of a line controller with a Human Machine Interface (HMI) at the top, middle layer of programmable logic controllers (PLCs) and, at the bottom of the control chain, the fieldbus links the PLCs to the components actually doing the work - such as the printers, sensors and switches.

Horizontal and vertical system integration

The majority of today's in-house and external IT systems are not fully integrated. Companies, suppliers and manufacturers are not connected, and neither are the different divisions within individual companies. With Industry 4.0, cross-company and universal data-integration networks will evolve to enable truly automated value chains.

IEC 61158 specification

The IEC 61158 specification standardised the Fieldbus family of industrial computer network protocols used for real-time distributed control. Despite many competing technologies, one single unified communications mechanism has not been realised. The final edition of IEC standard IEC 61158 allows eight technologies.

Industrial Ethernet

The Industrial Ethernet (IE) is the use of the Ethernet in an industrial environment. The IE is, therefore, controlled with protocols that provide determinism and real-time control. These protocols include CC-Link IE, EtherCAT, EtherNet/IP, Modbus/TCP, PROFINET, POWERLINK and SERCOS III.

Internet of Things (IoT)

The IoT is the network that connects cyber-physical systems so they can communicate or interact with other CPSs on the network, or the external environment.

Industrial Internet of Things (IIoT)

The IIoT is the use of IoT technologies in manufacturing. It involves adding big data, analytics and monitoring systems to create automated factory floors on a massive scale to improve manufacturing efficiency, safety, and productivity.

ODVA

ODVA (Open DeviceNet Vendor Association) was founded by Omron, Rockwell Automation, Square D and Westinghouse Cutler-Hammer. It's mission is to advance open, interoperable information and communication technologies in industrial automation, a core technology being EtherNet/IP. As of January 2017, Domino Printing is a member of ODVA.

OEE

Overall equipment effectiveness (OEE) and total effective equipment performance (TEEP) are two closely related metrics that report the overall utilisation of facilities, time and material for manufacturing operations. These top view metrics directly indicate the gap between actual and ideal performance. (Source: https://en.wikipedia.org/wiki/Overall_equipment_effectiveness)

OMAC

OMAC (Organisation for Manufacturing and Automation Control) is dedicated to supporting the machine automation and operation needs of manufacturing. OMAC is a leading organisation for the development and implementation of PackML. As of January 2017, Domino Printing is a corporate member of OMAC.

OPC Foundation

The OPC Foundation is responsible for the development and maintenance of the OPC-UA (Object Linking and Embedding for Process Control - Unified Architecture) standard. As of April 2017, Domino Printing is a member of OPC Foundation.

OPC-UA

OPC-UA stands for Object Linking and Embedding for Process Control - Unified Architecture. The OPC-UA is the interoperability standard for secure and reliable information exchange in industrial automation and the enterprise. The OPC-UA specifications define an interface between clients and servers, and servers-to-servers, so system components like PLCs, HMIs and any OPC-UA-aware device can share data without having to develop custom software device interface applications.(source: https://opcfoundation.org)

PackML

PackML (Packaging Machine Language) is an industry technical standard for the control of packaging machines, as an aspect of industrial automation. (source: https://en.wikipedia.org/wiki/PackML)

PROFIBUS

PROFIBUS (Process Field Bus) is a standard for fieldbus communication in automation technology most commonly used to operate sensors and actuators via a centralised controller in production factory automation applications. It should not be confused with the PROFINET standard for Industrial Ethernet. PROFIBUS is openly published as part of IEC 61158. (Source: https://en.wikipedia.org/wiki/Profibus)

PROFINET

PROFINET (pitch acronym for Process Field Net) is an industry technical standard for data communication over Industrial Ethernet, designed for collecting data from and controlling, equipment in industrial systems, with a particular strength in delivering data under tight time constraints. (Source: https://en.wikipedia.org/wiki/Profinet)

Simulation

3D simulations can mirror the physical and virtual worlds. This will allow plant operators to optimise the processes, products and other operating conditions in a virtual environment before testing in the real world. This brings obvious cost benefits as product quality can be increased and downtime reduced during simulation, instead of testing new ideas directly on the real factory floor.

Smart factory

Smart factory is a term to describe a vision of what industrial production will look like in the future. It would incorporate all of the ideas and innovations behind Industry 4.0. For example, in a smart factory the equipment will be able to monitor and improve processes automatically, and this machinery can be monitored and controlled remotely by the workforce.

Standards and Security

Industry 4.0 allows physical systems to be controlled from remote locations and brings together disparate areas such as mechanical engineering, logistics and IT. Such industries must work together smoothly, across the globe, and this flow of information must be controlled and protected using clear standards in a multi-sector environment.