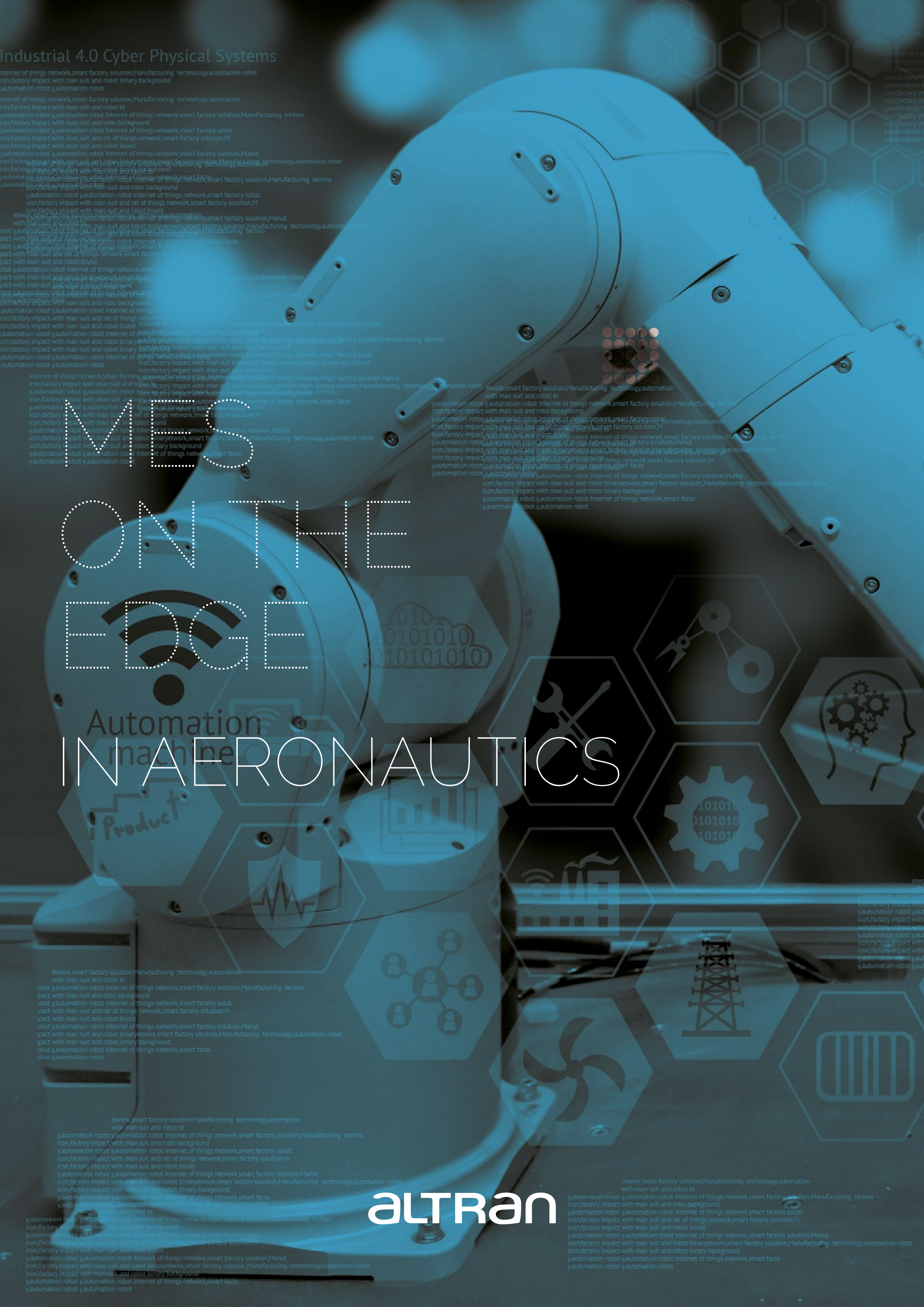

MES ON THE EDGE IN AERONAUTICS

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INTRODUCTION

Manufacturing Execution Systems (MES) are facing the fact that the concept of Smart Factory is becoming more a matter of present needs for manufacturers than a future wish. We will explore an overview of the latest technological advances and challenges in the manufacturing industry, which is trending towards the concept of Smart Factory and the advanced version of MES: an integral manufacturing operations management toolkit, capable of making and executing consistent decisions at different scales and different time horizons, ensuring compliance and continuously enhancing quality.

Currently, any legacy MES is designed for handling basic aspects related to the production floor, while being used by virtually all manufacturing workers with any kind of role in a factory. This system should, when connected to the industrial network and systems, provide visibility from the manufacturing floor to the different levels of the company, in a bottom-up stream. However, in most manufacturing industries, MES ends up functioning as a simple raw data collector, and as a manufacturer, you are lucky if you can fully exploit the amount of data collected.

Generally speaking, based on the description above, there are four main areas of competence which should feed directly from these MES outputs: **manufacturing execution performance management** (efficiency, availability and waste/scrap), **quality, traceability and planning**. To maximize this information feed, the manufacturing industry will have to deal with some significant challenges in order to fully develop the concept of Smart Factory. The manufacturing framework is becoming **an extremely dynamic and flexible environment under continuous development**. That is why legacy MES, given its current capabilities, has become obsolete faced with the upcoming requirements of Industry 4.0. This paper will discuss the potential rise of next-generation MES, **benefiting from emerging technologies such as Augmented Reality, Artificial Intelligence or Smart Networks for wearables and mobile devices**.

1 CHALLENGES FOR THE FUTURE IN THE MANUFACTURING INDUSTRY

Connectivity is crucial for the upcoming digital transformation: all industrial entities will communicate with each other, and everything will be omni-connected: machines, information systems and even humans, with data flowing vertically and horizontally, from machine to cloud where data will be stored and comprehensively analyzed. Today, factories that continue to use legacy machinery and obsolete systems are coping with serious performance improvement issues, and missing out on opportunities presented by digital technologies.

This is where the convergence between digitizing all inputs in a factory, where MES plays the key role in data generation, and then managing them by next-gen advanced information systems with embedded analytics capabilities, will make the ultimate difference: **transparency, end-to-end visibility and traceability, and real-time data availability** will be a must in the short term. Consequently, this processed data will offer a real preventive and predictive way of working by making it possible to anticipate failures in the production environment, facilitating adaptation of complex processes to take account of unexpected changes. At the same time, planning, material distribution and resources will be rebalanced in real time, with the aim of optimizing manufacturing operations to meet aggressive lead times and rates. All of these new attributes will lead to a **reinforced and empirical decision-making process every time at any layer of the company**.

As more and more data will be flowing in the system and supporting critical decisions, **the manufacturing industry is becoming increasingly aware of cybersecurity concerns**. Increased machine and user connectivity, as well as data value, are forcing the industry to develop security systems for their fully-connected equipment. An attack to these systems could lead to a massive loss of valuable information or a production line stopping due to hacking activities.

All these topics result in the need for hyper-efficient and flexible production processes that meet increasingly changing needs of customers, thus forcing companies to explore solutions related to the emerging techniques of massive data analysis and simulation of scenarios and services. We also need tools to harvest, process and analyze dynamic data streams in a way that not only ensures and improves performance, but also maximizes results through **identification and optimization of critical resources** and by anticipating any risks associated with operational decisions.

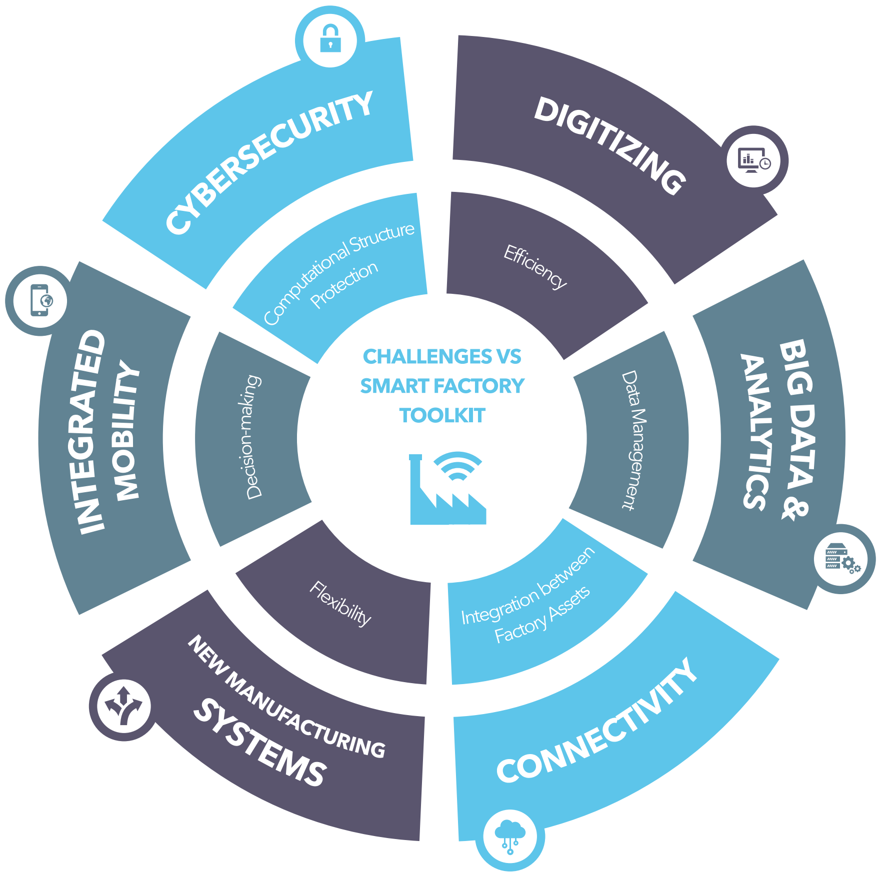

FIG. 1:
INDUSTRY 4.0 CHALLENGES RELATED TO MES CAPABILITIES

This is what the aerospace industry is experiencing at the moment. The increase in production rates by major aircraft makers due to globalization and customization will place extra pressure on every actor in the supply chain, requiring more and quicker innovation, adaptation and development skills. To cope with this pressure, **data value chains will have to be consistent and available in real time for further analysis**, placing MES in the spotlight as the main engine for data harvesting and mining.

However, the smart combination of new technologies and their application in the aerospace context will definitely help in this task, generating an **efficiency-based model** due to shared resources between aircraft programs and the capacity to **reduce industrialization time and increase productivity**. We envision a potential business case here for smart automation, as reducing the number of man-hours will make for **lower manufacturing costs; flexibility is also a key topic**, as the lead time to introduce new programs or lines will be drastically reduced, bringing down inventory and transformation costs.

2 CURRENT STATUS OF MES TECHNOLOGY

Regarding this next-generation MES-based data value chain, it is fair to say that one of the most often overlooked aspects in the performance analysis of productive systems is the role of variability in determining the behavior of systems. When we speak of randomness, we understand it as the idea that things happen within systems with certain variations from one time to the next. There are classic examples of randomness such as order delivery time, time between failures, or the time it takes to complete any activity or task.

All this leads us to state that if we want to understand, improve and prepare our production systems for this Industry 4.0 transformation, we will have to harvest and model, accurately and precisely, the variations inherent in the systems themselves. The static tools that have been developed so far, such as the current MES systems, can no longer respond to the impact of today's variations in production environments.

Variations and randomness are already present in almost all real-world systems, and not taking them into account is the first cause of inefficiency in the performance of any process. A couple of decades ago, factories used manufacturing resource planning (MRP) and enterprise resource planning (ERP) applications to manage data. However, these systems only allow for superficial control of the daily activity of the plant, with no connection to the other management systems and sources of data. Moreover, they act as isolated systems, unrelated to each other and to the different programs in the plant. Therefore, to **achieve a more exhaustive and fully informed control in which information is obtained and processed in real time, it will be necessary to use a system that allows for total interconnection of the company**.

Nowadays, some industries use an isolated version of MES on certain spots of their factories or machines, that acts as an isolated information island without taking into account any other interconnection of the factory data network. This MES market is categorized based on process and discrete industry, including food and beverage, oil and gas, chemical, pulp and paper, pharmaceutical, energy and power, water and wastewater treatment, life sciences and the automotive sector. Other process industry segments include textiles, as well as steel and aluminum. This generation of legacy MES is already obsolete because of its use and upgrade complexity, and also due to its inability to provide end-to-end factory system visibility.

3 A VISION FOR THE FUTURE OF MES ON THE EDGE

All in all, MES is now being implemented in highly innovative sectors, such as the electronics and metal mining industries, with real and tangible improvements regarding analytics and preventive capabilities. Indeed, the Industry 4.0 concept calls for a new generation of MES that can act and decide based on the large amount of data provided by the connected factory.

For this purpose, there are four undeniably important assets that will be the main drivers of this new MES concept: horizontal integration, connectivity through mobile equipment, cloud-based advanced analysis systems, and vertical integration.

→ DECENTRALIZATION

Decentralization is becoming essential for those manufacturers who have their future business vision set on a global environment. It allows for **better and tangible adaptation to the local context (plant, line, workstation) and conditions**, enabling decision-making in real time to solve problems in a highly demanding market. MES and industrial information systems are fundamental for a successful decentralized and worldwide management structure: to get real data, in real time, from any point of the globe, directly from the manufacturing floor.

→ CONNECTIVITY THROUGH SMART NETWORKS TO MOBILE DEVICES

Connectivity and mobile equipment play a key role for this worldwide visibility, as they will **enable this new generation of MES to manage all kinds of different equipment using specific functions** (augmented reality, real-time analytics, etc.), but always under conditions of interconnectivity. To streamline operation and understanding, there should be a well-defined interface that allows users to clearly visualize consolidated information such as key performance indicators. In addition, the growing use of mobile equipment will act as a support to make this information accessible anywhere inside or outside the plant, resulting in an integrated mobility system available at all levels of the company.

→ CLOUD-BASED ADVANCED ANALYSIS SYSTEM

The third asset to consider is in-cloud platforms and advanced data analysis, as connectivity and decentralization require a massive and highly efficient storage system to offer the data with minimum lag, high security features and pre-sorted data. These new concepts arise from the need to store and process all the data obtained in the factory or factories. The cloud is an infrastructure that provides storage, speed and agility in processing this data, while on the other hand advanced data analysis through innovative machine learning engines will allow for in-depth understanding of the manufacturing processes. This will result in a **high-quality and customized product while optimizing the global supply chain and cost savings due to full use of SaaS (Software as a Service) and IaaS (Infrastructure as a Service)**.

→ VERTICAL INTEGRATION

Finally, vertical integration refers to the need to interconnect information flows between the different layers of the company. This will require effective communication and transparency through all the information systems, **ensuring synergies throughout the Smart Factory: MES and ERP systems as main actors**, followed by all kind of entities such as smart sensorized workstations, robots, tools, jigs, and even humans. Vertical integration also requires a new connectivity paradigm to support seamless integration of these entities, whose number is increasing on the shop floor.

Those industries that are currently moving forward in the quest for a next-generation MES system will soon have the possibility of obtaining data in real time. Nowadays, most companies use a batch-based data processing system, which is oriented to processing large amounts of data volumes by groups over a period of time. The data is collected, processed and produced in batches, requiring separate processing for each step.

Another potential benefit of collecting data in real time is the possibility of launching a predictive maintenance program, both locally and globally, whereby local action is decided in real time based on global modeling and forecasting. MES will have a significant role here, as it obtains **the data in a continuous flow between the ERP and the shop floor, storing and re-feeding the specialized tools and techniques** (e.g. through pattern detection, as part of a predictive maintenance solution) to perform the requested maintenance task in real time. Upstream detection of failures would thus be possible thanks to the study of behavior patterns. In addition, corrective actions will be developed, extracted from the interpretation and analysis of the data.

Smart Factories are supposed to be dynamic and capable of reconfiguring their production system in response to manufacturing parameters and properties that are constantly changing. Therefore, to implement **a consistent Smart Factory paradigm, any industrial framework will require all kinds of large and essential updates**. All of this will allow manufacturers to gain a clear advantage over their main competitors by making products, workstations and systems intelligent and, when possible, also autonomous.

4 RECENT DEVELOPMENTS TOWARDS THIS VISION

As we have seen, the MES of the future will offer companies any number of benefits. But there's more. The use of MES in combination with disruptive technologies from industry 4.0. will unlock new value by bringing a huge number of possible applications covering almost every need within every department at all levels of the company.

→ ARTIFICIAL INTELLIGENCE

It is important to note that Artificial Intelligence will be present in all the technologies covered in this document, since **all data analysis goes through artificial intelligence engines**, from the harvesting to the categorization of specific behavior patterns of the procedures.

→ AUGMENTED REALITY

One of the technologies with a wider range of possibilities is Augmented Reality. The main feature of this technology is that it allows for both real-time and non-real-time visualization of all data to improve the information of the physical reality. With the integration of both systems, we could quickly obtain **a track-and-trace system of the product**, from raw material to delivery to the customer. Moreover, the use of AR glasses in smart storage systems where workers are able to check order status and inventory management will be a quick win. Consequently, it will increase speed and efficiency, decreasing failures since workers can work hands-free and have instant access to massive data sources.

Furthermore, this technology will allow workers to navigate the production line thanks to the use of tablets or glasses. Operators will be able to **check the current status of the workstations, as well as potential bottlenecks, and other parameters such as efficiency**. It will be possible to close orders or display operation instructions, both for newly incorporated workers and those who need further assistance during the process. In addition, augmented reality could be combined with integrated mobility, thanks to everything already being connected and available through the cloud. Mobile devices such as tablets or smartphones, and even AR or VR glasses, are booming.

MES-AR integration will make sense for quality control, by checking product or process defects using KPIs or visualizing the on-site defect through the glasses. Operators can also be alerted (regardless of where they are) about issues in real time, since the data process is constantly being fed from the cloud to each of the production lines and the devices related to it. Again, this allows corrective action to be taken immediately, saving time and money, without losing the pace and efficiency of production or affecting the quality of the product.

→ VIRTUAL REALITY

Not only will Augmented Reality play a significant role in combination with MES, but so will its partner technology: Virtual Reality. In this area, **simulation represents an important aspect** due to modeling and integration of factories in the virtual world. Both create a **perfect environment for a product design and development framework**, as any worker will be able to immerse himself in the virtual world in order to test the product parameters and the process design, checking feasibility or any possible modification in the future, for example in the layout to reduce costs of prototyping and tuning.

→ ADDITIVE MANUFACTURING

When designing products or prototypes, physical models or CAD programs are normally used. Nowadays, thanks to the rise of additive manufacturing, these expensive physical models will no longer be necessary. A **3D printer will build prototypes without producing any waste** because of inaccurate design reasons. MES will show the design parameters in real time and, in case of a design failure during the process, the **3D printer would stop itself, affording the opportunity to correct the design** before continuing with printing. This, will consequently lead to savings in material costs and lead time.

→ BLOCKCHAIN

Finally, **Blockchain will offer transparency and agility in data exchange at the local and global level**. It creates a network in which every department adds value to the data, from finance or human resources to production, and on to engineering, logistics, quality or procurement. This system unlocks new services and layers to customer, supplier and employee needs, offering **customized information about product status every time**. Moreover, this facilitates relationships with other enterprises and the creation of strategic alliances with the aim of gaining knowledge and creating **new technological synergies that could lead to new business models and a more profitable approach to these new businesses**.

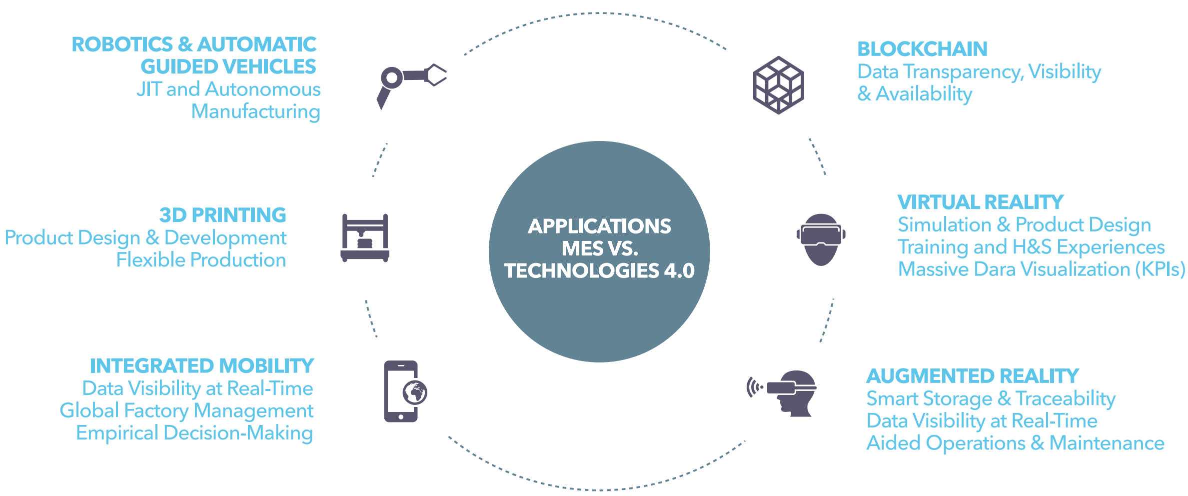

FIG. 2:
INDUSTRY 4.0 TECHNOLOGIES LINKED TO MES CAPABILITIES

CONCLUSION

Next-generation MES will be pivotal in the seamless integration of these technologies in support of more effective manufacturing processes. Looking to the future, what if…?

…future workers could become augmented operators? Wearing augmented glasses that recognize and scan the status of every operation without closing an order as a manual task.

…integrated mobility were to meet hologram technology in order to check an issue that has taken place or to have a look at the status of the production process? Through the hologram, a manager could be able to screen the digital twin that provides data from sensors installed in physical objects to represent their near real-time status, working condition or position.

…artificial intelligence could assist you like a human co-worker? You will have a full-executive overview of the plant, program or production-line levels, presented by your virtual assistant and available at any time.

…the aerospace industry could provide the same level of customization level as the automotive industry today? A customer will be able to customize their aircraft and check its status thanks to a blockchain-based app.

…MES could autonomously interact with wearables, robots and drones? The system could provide the order of replacing tools and consumables when needed, and the drone will automatically deliver the order on site and on schedule.

…Virtual Reality could allow real-time modification of the virtual layout of a plant directly from the application? This will take into consideration real-time data provided by the MES system, so the feasibility of the new production system would be guaranteed.

ABOUT THE AUTHOR

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in Aeronautics

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