ISSUES AND OVERVIEW OF SOLUTIONS

March 2018 Edition

THE GUIDE

INDUSTRY OF THE FUTURE TECHNOLOGY GUIDE

Alliance INDUSTRIE DU FUTUR

FRENCH FAB FOUNDING MEMBER

#industrie_futur

The Industry of the Future Alliance (Alliance Industrie du Futur), association law 1901, brings together and sets in motion the skills and energies of professional organisations, scientific and academic key players, businesses and local authorities, particularly in the French regions, to ensure in particular the deployment of the Industry of the Future plan. It organises and co-ordinates on a national level initiatives, projects and work striving for the modernisation and transformation of industry in France, particularly through the provision of digital services. To this end, it relies on the input of dedicated Working groups. Its actions are relayed across the regions by regional platforms, using the networks of Alliance members and local authorities to support SMEs/MSBs in the field.

The Industry of the Future Alliance comprises 35 members: the French Association of Mechanical Engineering (AFM), the French Association for the Development of Technical Education (AFDET), AFNeT, the French Association of Competitiveness Clusters (AFPC), Arts & Métiers ParisTech, Bpifrance (Public Investment Bank), CCI France (the Assembly of Chambers of Commerce and Industry in France), the Commission for Atomic Energy and Alternative Energies (CEA), the CentraleSupélec electrical engineering school, the Concrete Industry Studies and Research Center (CERIB), the Mechanical Engineering Technical Center (CETIM), Consult'in France (Syntec Strategy and Management), the Federation of Electrical, Electronic and Communication Industries (FIEEC), the Federation of Mechanical Industries (FIM), the Federation of Plastics and Composites, the French Institutes of Technology (FIT), France Industry, France Invest (French Association of Investors for Growth), the Group of French Aeronautics and Space Industries (GIFAS), the Group of Electrical Equipment, Control-Command and Associated Services Industries (Gimélec), the Mines-Télécom Institute, the French Welding Institute, the EMC2 competitiveness cluster, the ISTP (Higher Institute of Performance Techniques), the National Laboratory of Metrology and Testing (LNE), the PFA (Automotive Platform), the SCAP industry platform of the future (Cyber-Physical Adaptive Production System of the Lab-STICC), the RTE Electricity Transmission Network, the Federation of Machinery and Production Technologies (SYMOP), Syntec Ingénierie (Federation of Engineering Companies), Syntec Numérique (Trade Union of Publishers, and Technology consulting companies), TECHINFRANCE (French Association of Publishers of Software and Internet Solutions), the UIC (Union of Chemical Industries), the UIMM (Union of Metallurgy Industries and Trades), and the PACA Union of Metallurgy Industries and Trades (UIMM PACA).

It is chaired by Philippe Darmayan. Its Honorary Presidents are Pascal Daloz and Frédéric Sanchez.

AFM
ASSOCIATION FRANÇAISE DE MÉCANIQUE

AFDET

AFNeT

AFPC

ARTS ET MÉTIERS ParisTech

bpifrance SERVIR L'AVENIR

CCI FRANCE

cea

CentraleSupélec

CERIB

cetim

Consult in France
SYNTEC STRATÉGIE & MANAGEMENT

FIEEC

FÉDÉRATION DES INDUSTRIES MÉCANIQUES

FÉDÉRATION DE LA PLASTURGIE ET DES COMPOSITES

FIT FRENCH INSTITUTES OF TECHNOLOGY

FRANCE INDUSTRIE

France Invest
Association des investisseurs pour la croissance

GIFAS

Gimélec

INSTITUT Mines-Télécom

INSTITUT de SOUDURE GROUPE

EMC2

istp INGÉNIEURS

LNE

PFA FILIÈRE AUTOMOBILE & MOBILITÉS

Lab-STICC-SCAP
Industrie du Futur

RTE Le réseau de transport d'électricité

SYMOP
MEMBRE DE LA FIM

SYNTEC INGÉNIERIE

Syntec NUMÉRIQUE

TECH'IN FRANCE

UIC union des industries chimiques

UIMM
LA FABRIQUE DE L'AVENIR

UIMM
Provence Alpes-Côte d'Azur
LA FABRIQUE DE L'AVENIR

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PREFACE

▸ THE INDUSTRY OF THE FUTURE, A PROGRAMME FOR FRENCH INDUSTRIAL EXCELLENCE

On 20 July 2015, the Industry of the Future Alliance was officially created. Its role is to support French companies, particularly SMEs, in modernising their industrial tools and transforming their business models with new technologies, while putting people at the heart of the process. Its purpose is to re-situate French industry at the centre of the economic development of the country, which requires improving the competitiveness of the companies.

The awareness of that need dates back to the Gallois report of November 2012. The report highlighted the backwardness of French industry compared with its German and Italian counterparts, especially in terms of robotics. The idea then germinated that if France had missed the first train of modernisation, a second chance was available with the digitisation of the economy. Robotics and the Factory of the Future become respectively the 32nd and 34th strategic plans of the New Industrial France, launched in September 2013 by Arnaud Montebourg, then the Minister of Economic Regeneration.

In April 2015, Emmanuel Macron, then the new Minister of the Economy, Innovation and Digital Technology, proposed a streamlined organisation of the New Industrial France, capitalising on the achievements of the Factory of the Future Plan. This project is set to play a central role with a wider scope that now encompasses the modernisation and digitisation of industry, with greater means for taking action, a larger international focus and governance uniting the stakeholders in the offering at the regional and national levels.

In addition to the modernisation of the production tool, its purpose is to support companies in transforming their business models, their organisations, and their design and marketing methods in a world where new tools such as that those based on digital technology, additive manufacturing, new materials, or collaborative robotics are breaking down the divide between industry and services.

▸ FROM THE PRACTICAL GUIDE OF THE FACTORY OF THE FUTURE TO THE INDUSTRY OF THE FUTURE TECHNOLOGY GUIDE FOR SMES-MSBS

The Future Technology Development Supply working group (DOTF) has described the seven key technologies for the development of the Industry of the Future in the form of data sheets: digitisation of the value chain, process automation / computer-integrated material handling (transitics) / robotics, additive manufacturing, monitoring and control, composites and new materials / assemblies, the place of people in plants, energy efficiency and environmental footprint of companies / integration into the ecosystem.

The Industry of the Future technology guide is designed to demystify the Industry of the Future: it is possible, practical and pragmatic, and here's how to make it happen! It consists of fact sheets that highlight the levers of competitiveness and help a business leader to quickly take action. After the publication of an initial version in early 2016, the "Industry of the Future Guide version 2" sub-working group started its updating work in 2017 and published this new version for the Global Industry Exhibition on 27 March 2018.

The Federation of Mechanical Industries (FIM) and its unions, the CETIM, the FIEEC and its unions, the CEA, TECH IN France and the Syntec Numérique are at the origin of this work which began in 2014 and culminated in 2015 with the publication of the Factory of the Future Guide: a genuine reference work integrating an analysis of the transformation of companies, over and above the usual technological references, based on levers of competitiveness allowing a plant to transform itself and become more competitive and flexible, with a better impact in environmental, social and corporate terms. Without this invaluable work, originally overseen by the FIM, this new expanded version could never have seen the light of day.

Three years later, the Industry of the Future Alliance and its 35 members updated this work and published this new guide to the technologies of the Industry of the Future, enriched by new technological bricks or levers of competitiveness. The Industry of the Future today covers issues that no longer concern only the productive core but the entire environment linked to value chains and the transformation of business models by companies through the contribution of digital technology.

In the first part, this guide recalls the origin of the approach, defines the bases of the concept of the Industry of the Future and describes the major issues. For each issue, generic versions refer to more precise fact sheets that a company can appropriate and use as a guide to the subject in question. These fact sheets, describing the various components or macro-bricks of the Industry of the Future – whether they relate to new technologies, to modes of organisation or to specific items of equipment – always focus on their implementation in the company (including SMEs and VSEs). Together these macro-bricks constitute the reference work for the Industry of the Future.

This practical guide is therefore at the disposal of companies, to assist them in understanding the subject and to facilitate the implementation of the various components of the Industry of the Future when they decide to build a new plant or modernise an existing workshop. As a supplier of production equipment, these fact sheets are also a source of information with which to adapt the offering to tomorrow's demand.

The guide also contributes to public business support programmes as part of the Industry of the Future. Public authorities, aware of the importance of industry for our country's wealth and the challenges of our ageing societies faced with emerging markets, have decided to give the Industry of the Future lasting momentum. This includes a determination to modernise the industrial tool and improve its competitiveness through innovation and technological change. The authorities implement business support programmes to encourage Research and Development as well as investment in innovative technologies available on the market (additive manufacturing, robotisation, etc.). These programmes, referring to the Industry of the Future, have already been initiated.

Finally, this reference work is available to stakeholders in research, to help ensure that their many programmes, based on the issues involved in the "Industry of the Future", meet the needs of French industry and the country's economy.

THE ORIGIN OF THE APPROACH

The world today faces huge challenges, such as global warming, the depletion of natural resources, population growth and improved competitiveness.

▸ A POLITICAL APPROACH IN DEVELOPED COUNTRIES

For many years, there has been a steady decline in the share of manufacturing in the national GDP. A strong reaction is therefore needed for companies to regain productivity, competitiveness and profitability, and a capacity for investment and innovation, and thus remain engaged in global competition.

That depends on finding solutions to develop the competitiveness of companies, especially SMEs. It means meeting customer needs by developing "customer marketing" instead of "product marketing", providing more features, increasing product quality and safety, and moving towards solutions and associated services, in the framework of collaborative networking with other stakeholders: suppliers, specifiers, local authorities, R&D stakeholders, and so forth.

The Industry of the Future, as described in our foreword, is one of the answers for ensuring the competitiveness of mature industrial countries.

▸ THE INDUSTRY OF THE FUTURE, IN THE NEW ECONOMY

The new economy is characterised by the following major trends, which constitute both challenges and opportunities for the Industry of the Future:

1- a global level that is much more developed, shared and focused on optimisation. For the Industry of the Future, this concerns the issues of supplier chain optimisation, global collaboration platforms, traceability systems and ecological and energy saving;

2- a local level, that of the user's software bubble (the set of fixed or nomadic interfaces to which users have access) and their uses, by which users have access to all services they need in order to do their jobs with maximum *empowerment*. For the Industry of the Future, it is at this level that the vision of "plants for people" really makes sense;

3- an intermediate level that was previously highly bureaucratic and bloated, but which in the new economy is *lean*, automated, fast, dis-intermediated and de-materialised. It is thanks to the Internet of Things (local) connected to big data (global) that this intermediate level can be made very simple, and above all automatable. For the Industry of the Future, this level is that of the modelling and the control of production lines and supply lines, of processes and of the flows of value needed to deliver the services useful to productive labour (maintenance, training, etc.).

The Industry of the Future is part of this revolution. As such, the French project differs from many other international projects that often focus exclusively on the automation and modularity of production systems (cyber-systems).

Automation is important, but it is still based on the principles of the old economy and does not address the questions posed by *digital natives* or *makers*. The "Industry of the Future" programme clearly intends to address every level of the plant as well as aspects of the new economy. It is in this respect much broader in scope than its counterparts.

The new economy will also be the revolution of experience: after product development and then product-related services, the experience created by the product and the associated services becomes a critical factor. It characterises the user's feelings during use, first in the virtual world, then in the real world. It is a key parameter in a usage-centric economy.

► THE NEXT GENERATION OF AUTOMATED PRODUCTION SYSTEMS: CYBER -SYSTEMS

In the middle of the second half of the twentieth century occurred the third industrial revolution, its sources stemming from electronics, telecommunications, computing and the audiovisual media. An industrial revolution referred to as the fourth industrial revolution is on the move today, based on the increase in the speed of information processing and storage capacity and the massive development of communication networks.

This new technological transformation, linked more specifically to the advent of digital technology and characterised by the complete interconnection between machines and systems within production sites, both between themselves and with the exterior, is paving the way to a new organisation of production means, whether in the procurement, manufacturing, or product distribution stages.

This new industrial revolution is underpinned in particular by the massive introduction of cyber-physical systems, which can be defined as complex embedded systems designed to continuously interact with their environment through the association of physical, computing, and communication components.

In addition to this *machine-to-machine* communication, information technologies will increase the possibilities of communication between employees on the same site, on different sites or in different companies, for greater exchange and cooperation. The quality of these relationships will foster the emergence of collective intelligence that can be an important factor in the effectiveness of teams in companies.

The Industry of the Future concept not only optimises existing solutions but incorporates genuine transformations bringing new solutions for technologies and organisational modes. It results in seeing industrial production as a system with multiple dimensions: technical, organisational, economic, human and social.

Several avenues for developing production systems have been advanced in numerous recently published reports: the customisation of mass market products (*mass customisation*), the flexibility of industrial tools, the circular economy (the recyclability of materials, limitation or elimination of waste, etc.), the product-service system, the knowledge economy, the establishment of communities of stakeholders with high levels of interoperability, collaborative innovation, etc.

A HIGHLY DIGITAL TECHNOLOGICAL ASPECT, NEW MATERIALS AND NEW PRODUCTION PROCESSES

New communication tools of the extended enterprise are being developed and will impact the Industry of the Future: cloud computing, big data, social networks, collaborative spaces and the Internet of Things, to name a few. Access to new digital tools will accelerate the adoption of the most advanced manufacturing techniques, support the energy transition and improve the working conditions of operators.

Data is now central to any business strategy. Based on sensor networks, tomorrow's plants will continuously produce information on production processes, inventory management and batch routing, and will be permanently connected to the products they have manufactured. All of these data will need to be analysed in order to optimise maintenance and improve quality. In order to utilise them, the specifics of such mass, heterogeneous data requiring fast processing must be taken into account. The challenge is to transform raw data into high value-added information, enabling faster production, with better quality and at lower cost. A strategy will have to be developed in order to avoid wasting effort (time, money) to process useless information or, conversely, to avoid missing opportunities to create value by omitting to use the information available. The Industry of the Future will optimise its information systems, size them to be useful, and even resize them regularly and at a high level (Management review).

The products of the future made in our developed countries will be increasingly complex, made of intelligent materials. They will be connected, interoperable, safe... and will use constantly modernised technologies and advanced production methods (silent production, additive manufacturing / 3D printing, intelligent sensors, collaborative robots, artificial intelligence, etc.).

The products of the future will consist of materials in increasingly complex combinations, so that each of them brings its specific advantage to the final product (lightness, conductivity, resistance, hardness, etc.). To the increasing diversity of materials (new metallic materials, composites, nano-materials, biomaterials, etc.) will be added increasingly varied combinations between them. Assembly technologies are therefore one of the key points of the Industry of the Future.

Against this backdrop, cybersecurity is becoming a major issue: setting up means to prevent data piracy, and counter the risk of remote control of the production tool, is essential. The Industry of the Future will be collectively aware of its competitive advantages and will organise itself to identify and preserve its strategic information as best it can. In addition to technical means, protection will also depend on the awareness of stakeholders in the Industry of the Future on the financial value of these immaterial assets.

▸ A STRONGER SOCIETAL DIMENSION

Another challenge in the Industry of the Future lies in radically changing the vision of industry by French people. We must re-enchant industry and factories so as to attract talent and motivate young people, making people the focus for the Industry of the Future: involving employees in corporate projects, strategy and technological options (collaborative engineering, *open innovation*) as well as the development of corporate social responsibility (CSR), the well-being of employees and their training throughout their working lives. Employee support for company projects can only encourage their commitment and their involvement.

The French approach, making people the focus for the Industry of the Future, is what distinguishes it at the international level. Technology and organisation mean they can be freed from painful, repetitive tasks, so that they can focus on tasks with high added value.

The Industry of the Future is based on a set of bricks that manufacturers can assemble, integrate and use according to their needs.

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Being enterprising means taking risks by developing new ideas. These translate into new products or services to put on the market. Success will depend both on the innovative nature of the offering and the ability to provide it at "market" economic conditions.

Being enterprising also means consolidating an offering by improving it, day after day. This improvement can equally involve the nature of the offering and how it is produced. For industrial activities, the production tool in its ecosystem is an essential component.

Within the ecosystem, once all the rules (obligations, standards, etc.) and cost factors (salary levels, taxes, etc.) have been decided, it is the way of doing things that makes all the difference. If the customer, more than ever, is the driver of the company, it is the men and women who make it, by implementing new technologies. People, whether they are producers or not, are also part of this movement by requiring that the places where they live and work be close together, by being concerned about the ecological impact of products or the consequences of manufacturing processes. Unlike yesterday, all of these considerations must be taken into account at the same time.

The Industry of the Future seeks to encompass all of these issues.

1st challenge: the change in markets

There is no business without customers, in France or abroad, and no customers without taking into account their expectations, alternative offerings and the value of the offering.

2nd challenge: the technological offering

To make an offering competitive, connected production systems will remain closer to the customer. New processes, intelligent or mechatronic components and new materials will expand the scope of the offering or make it more competitive.

3rd challenge: a new organisational model

Rethinking manufacturing processes will be done with an organisation in which people at work will be more accountable, where the organisation will be more learning-based, more collaborative. This is the challenge differentiating the French model.

4th challenge: the environment is now an unavoidable factor

Production today can no longer exist without taking environmental aspects into account. The Industry of the Future not only bears its own impact as a constituent factor but, in addition, it must be designed as a model of sustainable development.

5th challenge: societal issues

Finally, producing in France implies the recognition of demographics, skills and living areas. The Industry of the Future is an integral feature of the city.

The Industry of the Future makes men and women the focus for this operational excellence. These five challenges indicate the solutions we must find so that our companies to stay in the global economic race. We therefore need to develop productivity, added value and thus the capacity for innovation and investment, and *ultimately* the competitiveness and profitability of companies, especially SMEs.

Each company will be able to model its "factories" according to the expectations of its customers, what it produces and its skills. Each team will be able to define the specific conditions for renewed, innovative and competitive production, a source of growth and employment. Each industrial site is, and will be, different. Each project is unique and customised. Each company must be able, depending on its size, to select its courses of action.

▸ MAJOR CHALLENGES OF MARKET CHANGES

For many years, markets have become globalised. Companies and production systems have to face a new context, more complex than before, in which the constraints and objectives are different and even totally new. The notions of performance and efficiency have broadened to embrace both the short and long term, and have taken on an ethical dimension. Performance must be ensured in an international environment in which technical, economic, societal and human uncertainties and variability have never been greater or faster.

The move upmarket

Basic competitiveness now depends more on the quality of products, the wealth of the associated services and their degree of innovation than on cost alone. A company's upmarket strategy consists in improving the quality and level of service of the products it offers, in order to increase its turnover by increasing the selling price of its products, and even to maintain or increase sales through the quality of its products. This is partly the opposite approach to that of reducing costs and offering low prices.

The high rate of technological change, as well as the massive distribution of the technologies involved, are permanent sources of innovation in terms of solutions and uses as well as production techniques and organisations.

See the fact sheets: "Value chains and offerings of the future"; "Monitoring, foresight and economic intelligence"; "Internationalisation and exports"; "Marketing breakthroughs and strategic breakthroughs".

Customer-driven change

The varied and changing requirements of customers drive production. It's a new approach to consumerism that needs to be addressed to create shared wealth and generate jobs. We have moved to a customised offer market that requires a new organisation of production.

The huge industrial sites intended to provide standard products to the widest possible geographic area will be replaced by smaller sites, designed to provide regional products and with production means tailored to smaller series, capable of meeting market demands that are increasingly volatile and unpredictable.

This challenge involves responding to customer needs by developing "customer marketing" instead of "product marketing", to give the products more features, to move towards global solutions and associated services, to increase the quality and safety of the products and to better control the company's production with the most competitive technologies most suitable for market needs.

Against this background, the company of the future will be all the more competitive if it is capable of discerning, before and better than its competitors, the future needs of its markets, in terms of products, services and process improvement. We naturally think of big data, or the Internet of Things. But people will have their rightful place, in particular for their creativity, their own entrepreneurial spirit and their ability to listen to customers.

See the fact sheets: "Digitisation of the customer relationship"; "New economic relations"; "Open and collaborative innovation".

Suitable processes

The Industry of the Future feeds on flexible, agile processes that produce objects in a cost-effective and competitive way. The Industry of the Future must be able to evolve rapidly with the acceleration in the rate of placing new products on the market. Flexibility and reconfigurability are therefore key issues.

Current markets are increasingly characterised by their variability, both in terms of the quantities of products to be manufactured or sold per period, as well as the features expected of them, which have to adapt to ever more specific needs in the context of shorter time to market. The production systems of the future must be profitable while being flexible and responsive.

See the fact sheet:
"Integration and digital sequencing of processes".

Design features more than products

The exacerbated international competition faced by suppliers of products and equipment requires that in order to maintain and develop their positions in their markets, they must continuously upgrade their offerings. The technical characteristics and the intrinsic quality of products have long been differentiating factors. Today, suppliers need to continuously add greater value for their customers by integrating multiple product usage features and associated services. Many of these features, which will address the major societal challenges (ageing of the population, health, safety and freedom, mobility, social contacts, energy transition, etc.) have yet to be invented.

The ultimate step consists in selling the use of a product rather than the product itself.

See the fact sheet:
"Product-service system".

Over and above the constant adaptation of the production tool to the changes in the products to be manufactured, these fundamental trends require profound changes in marketing – in order to understand and anticipate the needs and expectations of customers (end consumers or industrial intermediaries) – and in the organisation of companies, in order to provide the associated services. In this context, companies must organise and structure their strategic intelligence to monitor changes (technological, competitive, regulatory, etc.) and detect signals of weakness to better anticipate their next move.

See the fact sheet:
"Monitoring, foresight and economic intelligence"

These changes are all the faster as the sector vertically integrates the entire value chain.

Industry cannot escape these challenges: suppliers of intermediate products increasingly integrate the end-use of the products and will help to develop their market (e.g. lightening and resistance for a composite structure), while manufacturers of production machines, central to the Industry of the Future, will integrate multiple process functions, maintenance, traceability, etc., over and above the traditional performance characteristics of quality and productivity.

▸ MAJOR TECHNOLOGICAL CHALLENGES

The challenge lies in supplying the customer with the technical object and its features according to demand in the shortest possible time, at the negotiated price. Being certain of receiving the ordered product in the agreed conditions and on the scheduled date is an essential factor in decision-making and customer loyalty.

The rapid adaptation of processes for customisable products (small and medium-size series) involves the development of new agile manufacturing processes: the ability to very quickly reconfigure according to demand, with interoperability between machines and the improvement in cooperation between all of the stakeholders in the value chain.

New technologies at the basis of competitiveness

New technologies, whether integrated in the production process or in the product, are a major lever that companies can use to offer supplemented and safer solutions that are more flexible, more reliable and more competitive. They constitute a vast field for improving the overall competitiveness of the company. It is therefore essential to reduce lead times for innovation, design, production and distribution through the massive use of digital data models and exchanges, and to adopt management, design, manufacturing and distribution processes that best lend themselves to these exchanges.

The development and combination of new technologies such as nano-technologies, micro and nano-electronics, advanced materials, advanced production systems, mobile Internet, Internet of Things, cloud, energy storage, mechatronics and plastronics, etc., will have a major impact on the products and production systems of tomorrow. The main challenges concern both the technologies (physical principles, modelling and simulation, applications) as such and also their design, deployment and interaction with users.

Like interoperability, security is an important issue for the connected factory. Manufacturers must now comply with certain requirements in terms of cybersecurity.

The modernisation of productive equipment involves new processes, the acquisition of new skills and new ways of controlling production. Not all of the technologies needed to do so are necessarily available at the moment.

Digital and connected industry

The Industry of the Future is based on several lines of technology, one of which is common to all the others: Information and Communication Technologies (ICT). This can be used to integrate and connect technologies with each other and with the information system required for people to use them.

Information and Communication Technologies, accessible to industry, are paving the way for the connected digital factory. They enable in particular:
- continuous, instantaneous and integrated communication of information on production processes (design, manufacturing, logistics and maintenance) as well as the products manufactured;
- simulation of the product, process, workstation and even the plant, as well as of the logistics and supplier chain involved;
- self-testing and self-adaptation of production processes and equipment, as well as continuous product control.

ICTs are based on specific software: digital factory libraries, digital engineering, new extended enterprise communication tools and the Internet of Things.

The other lines of technology that are inseparable from the concept of the Industry of the Future are:
- the new agile manufacturing processes, making it possible to react very quickly to changes in demand (quantity, quality, product development, adaptation to specific needs, etc.), which can be quickly reorganised: assignment of operators, reorganisation of the workshop, interoperability of equipment, flexible and interactive relations with the network of suppliers;
- smart machines: production equipment capable of integrating intelligent components and using them to meet a given function. The complexity of the information and needs that are addressed qualifies the degree of intelligence of the equipment;
- new materials: products of the future will consist of materials in increasingly complex combinations, so that each of the constituent materials brings its specific advantage to the end-product (lightness, conductivity, resistance, hardness, etc.);
- control, monitoring and traceability: using miniaturised, energy-saving sensors with decision-making autonomy, and by new techniques of signal processing and digital imaging.

Information and Communication Technologies

ICTs are the backbone of the Industry of the Future, with particular regard to the aspects described below.

Digital engineering - modelling and simulation:
Tools to model and simulate the operation of a product or process (including a workstation) in a consistent digital environment and throughout its life cycle.

These tools can be used to develop the processes, and to optimise them in the virtual world, at very low cost once the initial digitisation investment has been made. This involves the implementation of a large number of co-simulations performed iteratively, involving all of the relevant disciplines in order to find the techno-economic optima for products and manufacturing processes.

Virtual prototyping before the material realisation of a product can be used to show a virtual reality tending to represent the object to be produced as faithfully as possible. It makes possible modifications easier without resorting to physical prototypes. Virtual prototyping saves a great deal of time in functionality testing and environmental integration.

Augmented reality refers to computer systems that can be used to superimpose a virtual 3D or 2D model on the perception we naturally have of reality, and in real time. It designates the various methods used to realistically embed virtual objects in a sequence of images. It applies equally well to our visual perception (superimposition of virtual images on real images) as to tactile or auditory forms of perception. Augmented reality makes it possible to accurately compare the virtual (what we intend to do) with reality (what actually exists and that we can see). This technology is key in particular for ensuring compliance with specifications, but also for instructions, training, etc. In industry, it has multiple applications and affects design, engineering, maintenance, assembly, the control of equipment, robotics, installation, impact studies, and so on.

See the fact sheets: "Virtual design and qualification of production systems"; "Product design and simulation"; "Big data infrastructures and distributed calculations"; "Process simulation software"; "Digital factory modelling"; "Augmented reality" ; "Virtual reality".

Digital Factory Software:

Various software systems form the digital factory library:

- Computer-Aided Design and Manufacturing (CADM);
- component library;
- production scheduling system;
- production management and computer-aided maintenance software packages;
- supervision: collaborative tool with a 360° vision of the process and dashboards;
- innovation social networks;
- Product Lifecycle Management (PLM).

See the fact sheets: "Production management and control"; "Business networks and integrated sites"; "Digitisation of the customer relationship"; "Digitisation of the supply chain"; "New knowledge and skills management tools".

Systems interfaces and communication protocols:

The Internet of Things makes it possible to couple objects together in a very simple way. It also allows objects to be coupled to sensors and actuators that enable them to be operated or to supplement their basic functions with additional value-added services. Finally, it can be used to connect all of the information involved to big data on the cloud in order to utilise these data at the global level.

A particularly important application is the use of sensors of the radio frequency identification (RFID) or other types to detect the presence of a product during manufacturing and obtain, *via* the cloud, the history of the product and its properties, as well as its planning sheets, instructions for use, and the final destination of the product. This type of device can thus be used to control production directly from these labels, in a much lighter fashion than from centralised systems.

See the fact sheets: "Machine communication and agility"; "Electronic components and subsystems"; "Reliability of mechatronic systems"; "Simulation infrastructures"; "Big data infrastructure and distributed calculations"; "Wireless industrial networks"; "Traditional industrial networks".

Secure information exchange:

The security of information systems is the set of technical, organisational, legal and human means required and set up to retain, restore and guarantee the security of the information system.

Security is a major issue for companies. Its purpose in the long term is to maintain the trust of users and customers. The purpose in the medium term is the coherence of the entire information system. In the short term, the goal is for everyone to have access to the information they need.

See the fact sheet:
"Cybersecurity".

Internet of Things:
The Internet of Things is a " *a global infrastructure for the information society that provides advanced services by interconnecting objects (physical or virtual) with existing or evolving interoperable information and communication technologies*[1] ".

It is "*a network of networks which, via standardised and unified electronic identification systems, and wireless mobile devices, enables the direct and unambiguous identification of digital entities and physical objects and thus the ability to recover, store, transfer and process the related data, without discontinuity between the physical and virtual worlds.*[2]".

With the Internet of Things, the physical object becomes – through its associated software intelligence – a genuine stakeholder in the value chains or processes in which it is involved, as are human beings, organisations or certain information systems.

See the fact sheet:
"Industrial Internet".

Mobile Internet, cloud computing, social media-oriented industrial applications:
The Mobile Internet is the set of technologies designed to access the Internet beyond workstations and desktop PCs.

The deployment of smartphones and tablets equipped with high definition screens, and access to 4G mobile networks in factories, facilitates access to the mobile Internet; website developments and numerous mobile applications dedicated to these smartphones have accelerated the spread of the Mobile Internet.

The factory of the future will rely on devices promoting information exchange (RFID chips, touch tablets); this connectivity makes operators more efficient and also allows remote control of production. The machine sends information about the current process, which can be used to create dashboards, issue alerts, and so on.

For example, products with an RFID chip will remember the task and the conditions involved in their production, thereby allowing them to control their own production process. When the product moves forward on the production line, the information is updated.

Cloud computing is a system of information and services provided via the Internet that can be used to supply and use the capabilities of computer systems, which is based on clouds: an installed base of machines, equipment, networks and software maintained by a supplier, which consumers can use as a self-service *via* a network...

Cloud computing therefore refers to a set of processes that consists in using the computing and/or storage power of remote computer servers through a network, generally the Internet. These server computers are rented on demand, most often for each specific usage based on technical criteria (power, bandwidth, etc.) but also on a flat-fee basis.

1. UIT.
2. *The Internet of Things* Pierre-Jean Benghozi, Sylvain Bureau and Françoise Massit-Folléa.

Cloud computing is characterised by its great flexibility of use: depending on the level of competence of the client user, it is possible to manage one's own server or to use only remote applications. According to the definition of the National Institute of Standards and Technology (NIST), cloud computing is access *via* a telecommunications network, on demand and as a self-service, to configurable shared computing resources. It therefore involves a relocation of the IT infrastructure.

A social network is a collection of individuals or organisations connected by regular social interactions. The term "social media" refers to various activities that include the use of technology, social interaction (between individuals or groups of individuals) and the creation of content.

Social media uses collective intelligence based on online cooperation. Through these means of social communication, individuals or groups of individuals who cooperate together create web content, organise that content, then classify, modify or comment on it, and combine it with personal creations. Social media uses many techniques, such as RSS feeds and other web syndication feeds...

In particular, social media enables collaborative multidisciplinary innovation by interconnecting multiple internal and external skills.

See the fact sheets: "Nomadic industrial applications"; "Open environment"; "Cloud and big data".

Big data:
Big data refers to data sets that become so large that it is difficult to work with them using traditional database management or information management tools...

It involves methods and tools for rapidly processing large amounts of unstructured data, in particular to orient their use with an associated probability of performing an event. For example, big data can be used to analyse production data in order to deduce the combination of parameters that has led to a situation of non-quality, thus enabling the prevention of such situations and continuous improvement of the processes involved.

See the fact sheet: "Cloud and big data".

New agile manufacturing processes

The concept of the Industry of the Future is based on innovative technologies, so that fluctuations in demand can be addressed as quickly as possible, but also to keep the production tool on the cutting edge. The increasingly rapid advances in technology in general require that a company limits the obsolescence of the production tool in order to control investments. If not, technological leaps can quickly become impossible.

The main processes in the Industry of the Future are described below.

Additive manufacturing:
Additive manufacturing combines all the processes used to manufacture a physical object from a digital model by adding material layer after layer (NF E 67-001). It includes direct manufacturing, rapid prototyping, 3D printing, and so on. A number of processes are involved that differ in the manner of depositing the various layers of materials and in the materials themselves. The use of multiple powders enables the creation of parts resulting from the fusion of several materials. The insertion of sensors in the materials will make the products of the future increasingly intelligent.

Examples of additive manufacturing:
- for polymers: wire deposition, laser sintering;
- for metals: Selective Laser Melting (SLM), Electron Beam Melting (EBM), Direct Metal Deposition (DMD).

See the fact sheet:
"Additive manufacturing".

Flexibility of conventional manufacturing processes:
The so-called "conventional" manufacturing processes (machining, forging, punching, cutting/stamping, compacting, assembly, etc.) have their place in the Industry of the Future. The challenge is to know how to implement on these *a priori* fully controlled processes the technological and digital innovations that will allow manufacturers to adapt, at controlled cost, changes in customer demand (the size of series, quality, customisation of products, etc.) and the environment.

The objectives are:
- to make the processes agile:
  - by avoiding the production of expensive and time-consuming tools,
  - by relying on modelling for part design, manufacturing process sheets and tools (by reducing start-up lead times for series production),
  - by using machines and equipment to save programming and cycle time, and even with robotic machining equipment,
  - by facilitating and automating the handling of parts in machines or equipment,
  - by making production management more flexible *via* the growing use of digital integration,
  - by implementing new materials with better performance characteristics;
- to control/optimise part quality/functionality and minimise scrap:
  - by implementing *in situ* control methods which will make it possible to check the quality objectives necessary to guarantee the performance of the process and/or to anticipate the maintenance actions to be carried out (inspections inside the tool or at the end of the production line),
  - by using self-adaptive instrumented machines,
  - by integrating indirect manufacturing operations in the tools (heat treatment, assembly, etc.);

- to capitalise on business know-how and expertise *via* online tools that will facilitate decision-making in both part and tool design and in the continuous improvement of manufacturing operations;
- to reduce energy consumption and environmental impacts:
- by using simulation to optimise energy transfer,
- by decreasing/eliminating lubrication.

See the fact sheets: "Automation, computer-integrated material handling (transitics), process robotics"; "Innovative or optimised forming and machining"; "Innovative or optimised programmable machines"; "Near Net Shape Processes"; "Innovative assembly".

Surface functionalisation:

Tribology and part surface requirements are becoming increasingly stringent and more multifunctional.

The objectives are:

- to implement more innovative processes in terms of performance and costs:
  - by investigating new processes: dry process treatments for example (plasma, steam, powder spraying, etc.), hybrid (duplex) treatment, etc.,
  - by developing robotisation for the hanging and moving of parts to be processed, the routing of which will be reorganised to allow better flow management in workshops,
  - by relying on the development of computer-aided production management (CAPM) and control of the parameters of production processes to better control the process,
  - by using simulation to choose the best material/process pair;
- to respond to environmental and health issues (classification of facilities, importance of ecological criteria, REACH, etc.) with solutions that meet the functional specifications:
  - by modernising the equipment related to the process itself and also to ancillary equipment,
  - by implementing "clean" alternative processes: solgel deposition, applicable to most common metals and deposited from non-toxic precursors and without CMR compounds (carcinogenic, mutagenic and reprotoxic), ionic liquids;
- to improve the service properties and/or performance characteristics of materials by adding innovative features to the surface of the parts (features that are sometimes combined): electrical, optical, magnetic, catalytic, tribological, aesthetic, antibacterial functions, and so on,
  - by relying on micro and nano-structuring surface technologies (laser texturing, shot peening, *skin pass*, etc.)
  - by optimising processes that are already industrialised (surface treatment – PVD (physical vapor deposition), CVD (chemical vapor deposition), shot peening, carburising, carbonitriding, etc.),
  - by implementing combined processes: machining-forming of metal parts, moulding of plastics with selective modification by laser integrated into the mould;

- to increase the durability of the surfaces with regard to service demands (friction, for example):
  - by adapting the treatment techniques, in particular diamond-like carbon coating (DLC) and nitriding, and by relying on the use of surface texturing and biomimicry;
- to reconvert products by giving them another function and thus open up new markets.

See the fact sheet:
"Surface functionalisation"

Assembly by innovative welding processes

Innovative welding processes must respond to technological challenges such as lightening structures, quality and cost control, and reliability and increasing the service life of the appliances. In many cases, the materials used will evolve, for example with the increasing use of aluminium alloys, steels with very high yield strength and so-called "noble" materials. The general idea is to have the right material in the right place, and the assembly process must be suitable for the materials used and their thicknesses.

Innovative welding processes are, of course, new processes, but also concern significant developments in long-established processes that meet growing needs:

- the capacity to produce multi-material assemblies, particularly between metallurgically incompatible metals or alloys;
- substantial increases in productivity, either in terms of welding speed, deposition rates or the number of passes, generally also thanks to robotisation;
- improvements in the quality of the welds, with processes guaranteeing the absence of unacceptable defects or which are more robust from an operating point of view to absorb the variability of preparation in mating faces.

Examples of innovative welding processes:

- in the solid state: friction stir welding (FSW) and magnetic pulse welding (MPW);
- by fusion: laser and laser-MAG hybrid welding, controlled short-circuiting MIG-MAG variants, high-penetration MIG-MAG variants.

See the fact sheet:
"High-performance welding technologies".

Microfabrication:
Market developments lead to a constant trend towards product miniaturisation. Mechatronics is an obvious example. It replies to the need to introduce more and more functions, and therefore services, into smaller and smaller volumes. Companies must then integrate microfabrication or even nano-fabrication technologies, or work with trusted partners. Today, virtually all macro manufacturing technologies have their alter ego in the micro world: micro-machining, micro-assembly, micro-drilling, etc.

Complete micro-factories are being developed, called Desktop Factories.

See the fact sheet:
"Microfabrication"

Smart machines

The Industry of the Future implies having machines whose intelligence makes it possible to free people from tasks that are either devoid or poor in added value, and to treat data in order to inform or react autonomously to a given situation.

The main technologies are smart machines and tools, and collaborative robotics.

Smart machines and tools:
Machines and tools incorporating intelligent components and subsystems bring together production equipment that can integrate information and use it to meet a given function. The complexity of the information and needs that are addressed qualifies the degree of intelligence of the equipment. Among the functions specifically addressed are the rapid adaptation to production change, the ability to perform several operations, communication between equipment, the optimisation of equipment life cycles, maintenance, the operator interface, or energy and material consumption, and self-adaptation loops (self-correction of the process parameters, for example: torque, cutting speeds, etc.). These types of equipment integrate mechanical, thermal, electronic and computer issues (mechatronics).

Here are the families:
- industrial robots and self-adaptive machines;
- collaborative robots (including cobots);
- multifunction machine tools;
- remote controlled equipment;
- additive manufacturing equipment (including rapid prototyping machines, 3D printers).

The Human-Machine Interface plays a very important role. Its objective is to increase the exchange surface between the equipment and the workers in order to improve the efficiency and competitiveness of the human/machine pair. It is therefore means and tools (hardware and software) implemented so that workers can control and communicate with their equipment, machine, line, and so on.

These means and tools ensure:

- the control of the equipment by the worker;
- the recovery of the data collected on the equipment and its surrounding environment;
- the multi-criteria analysis and processing of the data;
- the recording of events and data;
- the transmission of the results to the various workers involved. This transmission must be customised to each type of worker depending on the event, i.e. sending the right information to the right person at the right time and in the right form;
- the provision of other information, such as documentation, operating procedures, etc.

These tools make it possible to deploy "augmented people", that is to say, men and women who have access through these interfaces to all the information they need (drawings, manufacturing process sheets, instructions, technical data, training, historical data, etc.) but also, and most importantly, all the online services they may need (maintenance, quality support, procurement, utilities, etc.).

The result is that augmented people can be empowered and become true in-house entrepreneurs with new relationships at work.

See the fact sheets:
"Smart components"; "Smart machines".

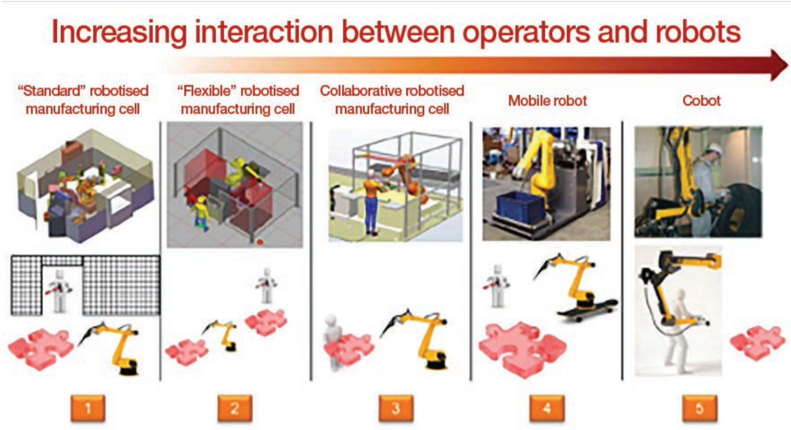
Collaborative robots:

A collaborative robot is a robot designed to work in a common area with the production operator. It integrates the safety functions needed for direct interaction with a human being in a defined cooperative work space.

Collaborative robots integrate enhanced capabilities for safe interaction with human beings and processes. They can be self-adaptive, that is to say capable of capitalising on the real-life situations encountered for reasoned decision-making.

The typologies of industrial applications can be classified into five categories, as shown in the graph below:

- "standard" robotic island: a solution without any planned interaction between the operator and the robot;
- "flexible" robotic island: a solution plus technical solutions in terms of safety;
- collaborative robotic island: a solution implementing collaboration between the operator and the robot, with interaction that can be occasional (as needed) or virtually permanent;
- mobile robot: a solution introducing robot mobility;
- cobot (a contraction of the words "*collaborative robot*"): robotic equipment used to assist operators in their tasks, including the mechanical advantage and a reduction in the hardship caused by a manual task.



See the fact sheets: "Assistance with movements and reducing work hardship"; "Cobotics and exoskeletons".

New materials

In the Industry of the Future, it is essential to consider the material/process combination from the design stage onwards (ex: Co-Cr metal powder for production of medical parts using laser fusion additive manufacturing processes). Similarly, it would be unrealistic to imagine advanced manufacturing processes, as well as process modelling, without thorough knowledge of the materials concerned (and especially new materials).

The new material/process combinations of the Industry of the Future must make it possible to:

- improve the economic performance of companies through processes that increase shop productivity and the quality of the manufactured parts;
- take into account societal and regulatory changes so that products are more respectful of the environment.

The development of materials will lead to:

- adapting conventional processes through innovations (e.g. high-temperature stamping on very high strength (VHS) materials);
- developing new methods of implementation (additive manufacturing).

Notable material developments include:

- for metals:
  - very high performance steels, lightening and safety specifications, while preserving their ease of implementation. Their resistance can reach more than 2000 MPa,
  - superalloys, developed for high-temperature applications. They have a high resistance to corrosion and creep, and better mechanical resistance in extreme conditions and/or in case of shocks. Nickel or cobalt bases, with the addition of rhenium or ruthenium, are envisaged for the construction of new aircraft engines with higher combustion temperatures or for new energy-efficient automotive engines.

  - light alloys with the use today of aluminium-lithium in aeronautics, titanium aluminides for turbine blades, or magnesium alloys for semi-structural parts such as bodywork elements or seats;
- for elastomers: new rubbers are emerging, offering specific properties by incorporating modified polymers and additives, or by special treatment during processing. For example, fluorinated elastomers are under study that can hold up to 315°C;
- for composites: the composite challenge in the context of the Industry of the Future will be to massively integrate composites into high-volume and, probably, high-speed markets. To do so, it will be necessary to:
  - reduce production cycle times (using composites with a thermoplastic matrix, for example),
  - develop "high speed" processes (automatic draping processes, pultrusion, liquid channel processes - RTM, filament winding, fibre or fibre tape placement, multi-material assemblies),
  - reduce costs (Net Shape processes, reduction of "material" and waste losses, hybridisation of processes to functionalise parts as much as possible),
  - in parallel with developments for organic matrix composites, ceramic matrix composites are being developed for high-temperature and abrasion resistance;
- nano-materials: nano-structured/nano-additivated materials to increase their performance characteristics.

Different constraints, including environmental *via* lightening, but also related to the optimisation of the distribution of the materials within a part or an assembly according to the stresses undergone, lead to the design of multi-material parts, made of materials chosen to satisfy specific needs (resistance to corrosion, lightness, mechanical properties, etc.).

Multi-material designs take advantage of the benefits of each component. They improve the characteristics of the products (lightening, shock absorption, etc.) as well as the perceived quality (surfaces, etc.), and respond to increasing problems of product complexity, while taking into account the compatibility of materials and environmental constraints. But they require the implementation of assembly techniques using dissimilar materials respecting these features, while guaranteeing a quality of connection ensuring that the properties of the assembly obtained are optimal.

The technologies implemented include:
- the assembly techniques of two dissimilar metallic materials: brazing, diffusion brazing and "solid" welding processes such as diffusion welding, friction welding, friction stir welding, magnetic pulse welding (MPW);
- the assembly techniques between a metallic material and a composite or plastic material: screwing, bonding, riveting-bonding, welding-bonding, clinching, overmoulding.

These new designs require:

- methodologies for dimensioning heterogeneous assemblies, determining behaviour models and the corresponding databases obtained by characterisation tests;
- means for qualifying the quality of the assembly obtained, preferably by non-destructive testing methods, and its durability according to the service requirements.

Composites are no longer new materials per se. The composite challenge in the context of the Industry of the Future will be to massively integrate composites into high-volume and, probably, high-speed markets. To do so, it will be necessary to reduce manufacturing cycle times, develop "high-speed" processes and multi-material assemblies, reduce costs, and so on.

See the fact sheets: "Very high performance steels, alloys and superalloys"; "High volume composites"; "Smart materials and adaptronics, functional materials"; "Non-metallic and biosourced materials".

Control, monitoring, traceability

The Industry of the Future, digital and connected, must logically have all the means to control the operations and expected functionalities of products and services, to monitor its production tool and its ecosystem (including its own impact) and to ensure the traceability of events, materials and transactions with stakeholders. This involves capturing, analysing and memorising information.

Sensors and actuators:

A sensor is defined as an integrated system comprising the means with which to make a measurement. It includes the detection, transmission and analysis of the information thus established. Sensors are intended to be integrated into complex systems.

There are three types of sensors:

- physical sensors, which measure a variation (displacement, temperature, light, mass, etc.) giving information about their environment;
- chemical sensors, which transform chemical information into a useful analytical signal;
- biological sensors consist of biological recognition systems made using biochips, micro-organisms, DNA, etc. They are seen as complementary to the other sensors because of their ability to measure at the molecular level.

The integration of sensors in materials is considered as a technological means to developing smart materials, because they make a link possible between the material and its outside world and thus gives the material adaptability.

The connection to the Internet of sensors in everyday objects, components, machines, containers, infrastructures and all types of physical objects, is a huge source of economic value. RFID chips with GPS, temperature sensors, humidity sensors, accelerometers, dynamometers, etc. can be implemented in most production lines and supply chains, making it possible to improve plant productivity with predictive maintenance and additional supervisory functions, optimise flow management and reduce variability as well as the costs related to inventory management.

A huge capacity for information processing is needed to use the data thus compiled, compare them and finally output the right information (cf. big data, cloud, etc.).

See the fact sheet:
"Autonomous and communicating sensors".

Control, monitoring, traceability

Products, made from increasingly complex materials, combine increasingly different technologies.

Verifying the compliance of the real product with the theoretical product (that resulting from the specification, modelling and simulation) requires greater control and monitoring of its performance characteristics throughout its life cycle, with two major challenges:

- monitoring the products and processes in order to anticipate breakdowns, increase availability and stagger maintenance operations, minimise repair time and costs, constantly know the demands on operation, make the product intelligent, monitor in real time (i.e. detect nonconformities or defects as soon as they are formed, and integrate models capable of analysing the danger of the defects, etc.), and estimate the residual life of a product in real time;
- inspection and traceability: for inspections that are faster, more discriminating, traceable, clean, without ionising radiation, automated, with less operating cost/time and without the need for skills, on new materials – with, over time, the possibility of switching to a complete "all-digital" inspection line.

To do this, we shall use:

- modern NDT technologies, with contact or contact-free, based on new signal processing and digital imaging techniques, as sensors develop using multi-elements, guided waves, active thermography, tomography, etc.;
- integrated sensors and operating models.

The difficulty for companies will lie in particular in the industrialisation and optimal integration of NDT methods and systems (most of the time, each product requires specific adaptation) in the manufacturing process.

NDT simulation tools will make it possible, before going on-site, to prepare the operating conditions, the choice of inspection method and optimisation of the settings.

See the fact sheets: "Innovative NDT"; "Data measurement and analysis"; "Optimisation of maintenance, predictive maintenance"; "Remote monitoring"; "Digital command-control systems".

▸ MAJOR CHALLENGES AT THE ORGANISATIONAL LEVEL

In the context of globalisation and the industrial specialisation of economies, the development of companies in Western countries is now based on a major strategy in three phases:
- **developing activities with high added value;**
- **focusing on creativity, quality and responsiveness;**
- **moving upmarket.**

To do so, companies need to work on their organisational issues and the supplier chain, as well as on the management of human resources as part of a reinvented dialogue between management and labour.

Total quality and operational excellence central to the process

International quality standards have moved towards total quality (TQM: *Total Quality Management*; NF EN ISO 9004: management of the sustainable performance of an organisation, quality management approach), which combines strategy, system, performance and human and social issues.

In the context of total quality, the stakeholders are:
- the customers;
- the suppliers;
- the shareholders;
- the employees;
- and society in general.

Optimal quality lies at the meeting point between the explicit or implicit needs of all of these stakeholders.

A new organisation of production – flexible, easily reconfigurable and adaptive, capable of responding in less time to shipping from distant countries – must emerge. The lead times and quality of customised production must be arguments to counter mass production.

The flexibility of the production facilities must be accompanied by the agility of the organisations involved, providing a framework for more versatile, multi-skilled operators that favours the emergence and development of cooperative and innovative processes.

Operational excellence, a systematic and methodical approach carried out in the company, is designed to enable continuous improvement of production processes, both in terms of productivity and product quality and reducing costs of all kinds. This approach uses a wide variety of concepts, methods, techniques and tools, including: 6 sigma, AMDEC, Kaizen, Kanban, lean management, etc. Operational excellence, focusing on the satisfaction of the end-customer, promotes the sustainability of activities.

Beyond the company as such, the deployment of new digital technologies is intended to accelerate, facilitate, and change the relationship between different stakeholders in the value chain. Former dictatorial customer/supplier relationships must give way to the extended enterprise based on a win/win model. These new inter-company relationships, with leaders and partners united around projects with the same values, must enable the pooling and sharing of know-how and knowledge, skills, experiences and even industrial equipment within the framework of *manufacturing as a service*.

And the aim is always the efficiency, competitiveness, and acceleration in growth of each partner, who are thus stronger together than when separate.

These partnerships can be local or international, with technical or university centres, with any partner, of any kind, in order to accelerate and improve.

See the fact sheet:
"Product quality management".

Tools of operational excellence

- The 5S workplace organisation method – based on the initials of 5 Japanese terms: *Seiri* (sort), *Seiton* (set in order), *Seiso* (shine), *Seiketsu* (standardise), *Shitsuke* (sustain) – is designed to eliminate the causes of many small problems that are sources of loss of efficiency. It is one of the first methods to implement in a lean management approach. It is also designed to change the mentality of operators and management.
- VSM (*Value Stream Mapping*) – analysis of the value chain, physical flows and production run times (from the input of raw materials to the dispatching of packaged finished products) – defines the priority issues and actions of a lean management *roadmap*.
- Lean management is a system of work organisation that seeks to involve all of the stakeholders in order to eliminate waste that reduces the efficiency and performance of a company, a production unit or a department. To do so, a lean management approach sets itself the goal of eradicating three "demons" from the organisation of work: everything that is without value, the work overburden generated by unsuitable processes, and finally unevenness or irregularity.
- Lean management focuses on overproduction, waiting, defects, over-processing, transport/interruption of flows, unnecessary motion and inventory. To obtain sustainable results, it relies on continuous improvement, with a strong involvement of all the personnel concerned by the processes to be optimised.

- Visual management relies on the transparency of results in real time, in an attempt to improve responsiveness to problems when found. Each work area or department must have its own indicators, displayed on-site. Significant deviations from the set objectives must result in an analysis and corrective action plan.
- The SMED method (*Single-Minute Exchange of Die*) is a method for analysing and reducing production (or series) changeover times, the main purpose of which is to reduce the size of the batches to reduce the value of inventories (finished products and intermediate products).
- Total Productive Maintenance (TPM) is a method based, with the participation of operators, on field observation and the resolution of breakdowns that affect a facility. Two indicators are used in this method: MTBF (*Mean Time Between Failures*, and MTTR (*Mean Time to Repair*). If the method succeeds, it should result in an increase in the OEE (*Overall Equipment Effectiveness*), which is the main indicator of *lean manufacturing*.

See the fact sheets: "Development of intangible capital"; "Lean approaches and tools"; "Approaches and tools for change management".

Inventing new collaborative systems

Collaboration is central to innovation for the products and processes of tomorrow. Collaborative systems are social networks tailored to technical issues, enabling the sharing of information; the prioritisation of ideas; and the management of technical controversies, projects and programmes, or portfolios of products, etc.

These forms of collaboration can be deployed within the company and externally, for *outside-in* innovation. Of particular importance is co-innovation with customers, making it possible to retain them from the early stages of the product life cycle. Collaboration equally concerns the design (of products or processes) and their performance. Design collaboration helps to define products or processes that are functionally innovative and therefore market-winning. Performance is used to continuously optimise production conditions, as well as quality, with a direct impact on productivity and cost indicators.

The Industry of the Future will need to take into account changes in workplace relationships introduced by these collaborative practices, including new organisational possibilities for remote collaboration.

Another way of conceiving mobility, especially that of production modes, must be applied – mobility in the broad sense (product, people-skills, production, organisation), with deeper ties to the place of origin, which will also help to organise its integration into globalisation. This new mobility will encourage communication in teams on different sites and in partner chains.

See the fact sheet:
"Technological or geographical alliances".

Organisational flexibility

The Industry of the Future will have to be intelligent and have flexible production methods, reconfigurable production tools and human resources with suitable skills. It feeds on flexible, agile processes that produce objects in a cost-effective and competitive way. Flexibility and reconfigurability are therefore key issues. With this necessary flexibility (but also with the increasing complexity of products), the machines of the future will have to interact and cooperate with the operator. It will be necessary to develop new professional skills.

In a production system based on advanced technologies, human resources must be constantly renewed so that skills can quickly adapt to technical developments. In the years to come, it will be necessary to better identify the resources to mobilise in the organisation of work and training in order to develop skills.

See the fact sheets: "On-demand real-time work preparation"; "Management and control of production"; "Integration of the human factor".

A quality management system refocused on the added value of employees

The quality management system of the Industry of the Future will have to be built around the dynamics of processes and the development of team empowerment. Autonomy and ease of decision-making will only be exercised through clear rules, with value-added managerial processes for motivating engineers, technicians and operators who cultivate a spirit of commitment to efficiency. The fluidity of performance management will be favoured by the use of digital tools for the factory of the future such as social networks, information-sharing tools, mobile web, augmented reality, intuitive HMIs, and so on.

The latest version of ISO 9001 (2015) recommends that the quality system should include an understanding of the needs and expectations of the interested parties. In this sense, it promotes taking the plant ecosystem into account in the implementation of processes. It also calls for a risk analysis and improvement opportunities at each level of the company that will give a more important role to the men and women working in the plant.

See the fact sheet:
"Integration of the human factor".

Logistics of the future

The logistics of the Industry of the Future will be served by computer tools that are increasingly precise and increasingly communicating. It will also focus on the interpenetration of logistics and business management tools in order to synchronise logistics flows and workflows, and implement dynamic production planning.

The concept of supply chain management is evolving beyond logistics and inventory management, material sourcing and transportation.

It now includes:

- coordinating/managing flows (materials, tools, personnel, money and information) to improve the company's performance, by adapting to the multiplicity and complexity of products, to market fluctuations and to the customer's organisation, all in real time;
- improving cooperation between the players of the value chain by relying in particular on ICTs (electronic catalogue of components, de-materialisation of material certificates, etc.).

There are many challenges involved:

- management of huge flows of information and total traceability;
- mastery of mobile communication technologies;
- complete interfacing with the supplier organisation and the customer organisation to minimise the volumes stored and get rid of cost-intensive warehousing.

Products must be taken care of as soon as they leave the production system of the supplier or subcontractor until they arrive on the assembly lines of their customers, at just the right time. The Industry of the Future will have to fully master the integration of logistics into its own production system. It is an essential component of the value chain.

The upstream and downstream logistics chains will have to be organised to allow the repatriation of products at the end of their service lives, either to the manufacturer's premises or to processing platforms forming specialised market sectors. Based on providers of independent logistic services, varied in size and recovery areas (regional, national, international), they will have to develop new ways of working together. These chains will have to constantly reconfigure themselves in order to minimise the resources used and therefore limit their environmental footprint.

See the fact sheets: "Digitisation of the supply chain"; "Automation, computer-integrated material handling (transitics), process robotics".

Vertical and horizontal integration

Insofar as the quest for economic efficiency drives companies to improve their networking, new forms of collaboration are emerging, structured around the deployment of information technologies:

- integration of Industry of the Future all along the value chain from supplier to customer (vertical integration);
- reinforced collaboration between the various departments of the factory of the future, from process engineering to quality control (horizontal integration) and marketing.

This evolution will have major impacts on the relations between all of the stakeholders, inside and outside the factory: optimising relations with suppliers (sharing the planning of the supply chain), involving customers *via* collaborative design systems, the use of collaboration with skills centres (technical centres, research laboratories, pooling of resources, etc.) and better internal collaboration between the various departments (design, process engineering, manufacturing, logistics, purchasing, quality, product marketing, etc.).

It is crucial to ensure that the different models of company management used at different levels are vertically integrated. It is also essential that the various levels of modelling can continuously evolve without disrupting production. For example, in the same period of time we may need to introduce a new supplier and cooperate with them, set up a new procedure for monitoring ecological flows, optimise a production line, deploy a self-sustaining logistics line, develop an additive manufacturing station, equip personnel with augmented reality glasses displaying production instructions, implement a robotic workstation, install a system for tracking products using RFID tags and cloud connection, etc. It is obvious that it must be possible to study and implement these initiatives in parallel, without disrupting production. This is where digital technology is essential, to continuously manage the digital twin of the actual plant and plan the deployment of all these competitiveness initiatives.

See the fact sheets: "Integration and digital sequencing of processes"; "Digitisation of the customer relationship"; "Technological or geographical alliances".

▸ MAJOR ENVIRONMENTAL ISSUES

In a global context of tensions over the supply of raw materials, energy transition and the fight against climate change, each plant must limit its environmental footprint and that of its products as much as possible.

Reducing waste and nuisances, energy efficiency, the efficient use of resources and sustainable siting within a region are major environmental issues.

Using low-carbon technology and fewer non-renewable resources, industrial sites must implement production processes with high energy and environmental performance characteristics. They will form part of an industrial and territorial ecological process (pooling of flows and resources between companies that are close to each other).

In buildings of high energy and environmental quality, they will use a growing share of renewable energies.

In the development of their products, they will integrate environmental management at every stage of their life cycles. In particular, they will implement the principles of the circular economy that are designed to "reduce, reuse, recycle": their products will be eco-designed and easily recyclable and their lifespan increased (remanufacturing, retrofit). They will combine their products with service offerings based on the product-service system in order to maintain their control of a product's entire life cycle.

They will reduce their carbon footprint, in particular linked to their logistics activities and the work-related travelling of their employees.

All of these operations must have a positive impact on their overall economic performance.

Integrating the plant into its local ecosystem

The main challenge will be to demonstrate that the industrial site, which is economically competitive, can be integrated into urban (near living areas) or rural ecosystems. The aim will be to develop technical solutions to reduce noise, air and water emissions and use clean production technologies. In addition, buildings of high energy and environmental quality will have an architecture integrated into the local landscape.

Beyond the purely technical issue, a second concerns the organisational and relational integration of the plant into its ecosystem, based on:

- logistics and access to transport systems and infrastructure in order to optimise incoming and outgoing flows to and from the plant ("last mile logistics" with clean vehicles);
- integration into the urban system and transport network for staff and visitors (integration in sustainable neighbourhoods, logistics for waste disposal and treatment).

Buildings with high energy and environmental quality

Make it functional, low-cost and beautiful! This issue is not new in fact. In the course of industrial history, these three themes of architecture have been implemented to varying degrees and with varying degrees of success.

In the 60s and 90s, functionalism prevailed with factories whose sole function was to house often large and inexpensive workshops. Space became, for a time, a minor issue with the development of the automobile, pushing factories either into the suburbs or even the countryside. Reconciling the imperatives of cohabitation between production sites and living areas has become a challenge once again.

Industrial buildings (for production, storage) must first and foremost meet their functional needs. The organisation of flows, their potential flexibilities in space, the necessary power supplies of all kinds (energy, compressed air, gas, heating, electricity) are to be taken into account so that their management and their purposes remain adaptable.

Other considerations have become more pressing today. Buildings must minimise a company's carbon footprint. From the design stage, energy resources and non-productive consumption must be taken into account. It is not uncommon that more than 50% of the energy of an industrial site is consumed by heating and the rest by the process. For warehouses, the energy issue is different: the presence of personnel being more limited, heating needs are equally so.

The use of materials is essential to give carbon credits to the plant, free of fossil energy (through the use, for example, of photovoltaic energy) and revegetated. The industry of tomorrow will be environment-friendly and more acceptable thanks to pleasant surroundings for workers. In current designs, glazed surfaces are banned because of their cost. But light is an important factor in the quality of life at work as well as for comfort. The same is true of noise. Applying sound reduction techniques is also possible for the comfort of all.

Buildings must be designed so that simple modularities can be implemented. Current techniques and materials must make spaces more legible (no poles for example). They must be economic in terms of land take, given their proximity to residential areas. Traffic areas and commuting practices will need to be dealt with.

Outside, buildings must integrate the urban landscape. The treatment of façades (various materials, alignment breaks, colours, etc.) make production sites less uniform and above all more welcoming. From a consumable amortised over 15 years (this is true for warehouses), industrial buildings must become living quarters for longer periods, thus justifying the potential additional cost of development and construction more in line with their urban integration.

But 80% of today's buildings will still exist in 30 years' time...

See the fact sheets: "Adaptation of energy consumption"; "Technologies for reducing energy consumption".

Design and produce by controlling material inputs

The main issues relating to the flow of materials entering the production system concern:
- the accomplishment of the function requested of the product by optimal sizing while guaranteeing safety, security and performance characteristics. Materials are then saved by better control of the factor of ignorance (or of safety);
- the implementation of transformation processes that can directly save material and energy in order to manufacture products with performance characteristics comparable with those obtained by traditional processes with similar manufacturing costs.

Products and manufacturing processes are designed jointly.

The objectives therefore concern:
- sizing methods, and especially the replacement of deterministic design methods (everything is done so that there is never any breakdown) by reliability-based methods that take into account the variability of materials, manufacturing processes and uses, with a risk management approach;
- manufacturing processes that reduce material consumption, such as additive manufacturing;
- linking production scheduling and forward-looking methods of raw materials procurement in order to optimise the management of purchases, lead times and inventories.

Decreasing the consumption of materials, energy, water, etc. also involves a reduction of scrap and therefore better control of the manufacturing process. This implies having sensors and systems for monitoring manufacturing processes, making it possible to:
- control the transitional phases of ramp-up and production shutdown;
- detect any deviation in process parameters;
- detect parts with defects as soon as possible;
- implement predictive maintenance based on measurement.

The idea is to have reliable models adapted to the needs of the company, so that the technical, economic and environmental relevance of the solutions envisaged in terms of design, dimensioning and manufacturing can be quickly assessed in order to ensure the competitiveness of the company.

See the fact sheets:
"Circular economy"; "Ecodesign".

Ecodesign, recycling

Ecodesign consists in integrating environmental issues right from the design phase of systems (whether they be products, services or industrial processes), in order to reduce their environmental impact. If we take the example of a product, the first step is to assess the environmental impact of the current product before implementing improvement alternatives. This assessment takes into account all the stages in the product life cycle, from the extraction of materials to its phase of use and until its end-of-life. This is referred to as the "cradle to grave" or "cradle to cradle" approach.

Several methodologies are available to carry out this assessment: life cycle analysis (standardised ISO 14040-44, which requires large-scale databases and long study times) or, for mechanical products, a method simplified for use by SMEs (standardised NF E 01-005 and CEN/TS 16 524 at the European level).

Possible ways of improvement will indicate whether it is more relevant to act primarily on the product use phase (energy efficiency, water consumption, etc.), the upstream phase (reducing the consumption of resources and materials) or its end-of-life phase (design for disassembly to facilitate recycling or reuse).

These approaches are most effective when the problem is dealt with "at the source".

See the fact sheet:
"Ecodesign".

The objective will be to promote these approaches within companies and to continue the work undertaken in standardisation to make the methods, tools and data even more accessible, so that the following can be developed:

- dynamic approaches to the life-cycle analysis (LCA) as well as its link with economic models of industrialisation and product distribution;
- data and access to databases of materials and processes (including assembly);
- coupling the initial LCA with the reality of the product throughout its life, through the integration of maintenance and upgrading during its lifetime.

Another objective of ecodesign is to design products that will make their reuse and recycling easier, while developing the integration of materials produced by recycling.

In particular, it involves designing and manufacturing products that can be easily disassembled in order to:

- facilitate the evaluation of assemblies and parts after scrapping that could regain product status after being analysed, appraised, repaired if necessary and requalified for reuse within a certain perimeter;
- facilitate the disassembly and deconstruction of products in order to facilitate their processing by recycling channels.

This implies:

- an evaluation of material characteristics, the identification of defects and an evaluation of their harmfulness;
- the sizing of products incorporating recycled and requalified parts or sub-assemblies after repair if necessary;
- disassembly of products, cleaning, and possibly disinfection and decontamination.

See the fact sheet:
"End-of-life of the product".

The final goal is an industrial imperative to develop materials containing recycled inputs.

To do so, it will be necessary to:

- characterise them and access their behaviour laws;
- develop the processes to implement them under economically favourable and legally stabilised conditions.

The identification of relevant recycling channels, and possibly actions helping to create new waste streams, to ensure the link with the circular economy based on local ecosystems. Mechanical engineers, as suppliers of capital goods for other industrial sectors, will also have to design and industrialise machines that can carry out and automate the disassembly of products, sort waste, prepare them for reuse, and use materials containing recycled inputs.

See the fact sheets:
"Circular economy"; "Waste recovery".

Energy efficiency and reducing the carbon footprint

The main challenge is to reduce energy consumption and CO_2 emissions as well as the associated costs. To do so, we can develop, validate and implement system approaches for energy control by integrating the plant as an interconnected energy system into its ecosystem. The plant becomes energy-efficient, by being both a consumer and supplier of energy networked within its ecosystem (industrial zone, agglomeration, etc.), in an approach based on regional ecology. It will also be necessary to optimise the internal production system. Processes that consume and supply energy, parts of the plant, are then organised to optimise energy management by acting at the machine and process level, which are parts of the production system.

The idea is to have tools and methods making it possible to:

- intelligently interconnect the plant and its energy ecosystem: integrate it into smart grids and site energy management tools;
- store the energy produced by the plant, in order to reduce the consumption of energy purchased;
- manage multiple internal and external energy sources with different characteristics (solar energy, wind energy, energy recovered from the production system) and guarantee quality of the energy entering the production system;
- optimise processes to limit their energy consumption by using machines operating with multiple energy sources and streamlining processes in order to optimise them from an energy point of view;
- optimise industrial processes and utilities (compressed air-steam) in order to limit their energy consumption by technological developments focusing on basic operations or functions (better heating or better cooling, reducing friction, lubricating more efficiently, etc.);
- optimise the energy consumption of the plant by taking into account the needs of the operators (lighting, ventilation, air conditioning, etc.).

More specifically, with regard to the reduction of carbon emissions, it should be noted that all the aforementioned actions aimed at reducing the environmental footprint help to reduce the carbon footprint of industrial activities in the broad sense (manufacturing, product design, etc.).

In particular, companies, through their knowledge of their own situation (highlighted by greenhouse gas (GHG) balances or other assessments), take action in order to:

- encourage the purchasing of materials from the recycling sector, while collaborating closely with their suppliers;
- optimise and manage their energy consumption more precisely, for example by continuously improving the energy efficiency of their processes by setting up counting plans and raising employee awareness;
- source materials and semi-finished products locally;
- reduce the transport footprint, including the implementation of an company or inter-company travel plan (shared common means of transport, incentives to use public transport or carpooling).

See the fact sheets: "Adaptation of energy consumption"; "Technologies for reducing energy consumption"; "Clean processes".

▸ MAJOR CHALLENGES AT THE SOCIETAL LEVEL

The impacts of the activity of companies, particularly industrial ones, on society have become more significant. Not only do they affect the specific field of activity of these companies, the production of goods and services, but they also have a large number of knock-on effects (externalities) which can be seen in many fields such as the operation of the economy, health, the environment, solidarity, etc. The development of corporate social responsibility is neither a pious wish nor an obligation, but rather the transformation of a techno-economic system underpinned by values and rights.

The industry must come to terms with society and fit harmoniously into its local ecosystem. It must reduce the nuisances it creates so that it can be located as close as possible to town centres and thus limit the need for employee transport.

New professional skills will be needed. New business lines are emerging and will continue to emerge. To cite the French management employment association APEC, (the emerging professions in 2015): digital data manager, cybersecurity engineer, robotics technician, mechatronic engineer, e-CRM manager, virtualisation engineer, supply chain manager, strategic workforce planning (GPEC) manager, and so on.

In a production system based on advanced technologies, human resources must be constantly renewed so that skills can quickly adapt to technical developments. People will need to adapt and hone their skills to be effective under these new circumstances. It is therefore essential to properly identify the resources to be mobilised in the organisation of work and training in order to develop skills. Similarly, the capitalisation of skills, help for older workers, setting up collaborative, intuitive and efficient processes, intuitive e-learning, self-training, etc. are essential to have the necessary human resources.

Finally, it is essential to improve the image of the company by giving an attractive vision of the Industry of the Future for younger generations. The future of industrial and production systems, which has only been tackled in previous years by counting the number of jobs lost and plant closures, has become an issue of development for French and European companies. One of the major political aims of the "Industry of the Future" plan is to maintain and develop industrial activity that is strong and innovative and creates exports, wealth and jobs.

The Industry of the Future is based on people and their know-how.

It focuses on the well-being of employees, the development of their skills and their collaboration in the company project. It must attract talent and capitalise on the expertise it needs for its development, and make its "human capital" grow. Its organisation helps cultivate the efficiency and creativity of its employees, who are also encouraged to continuously develop their talents and abilities. Their involvement in and contribution to decision-making are both encouraged. The reduction in certain tasks (greater volumes of process-related information are processed directly by machines) provides opportunities for employees to better use their individual and collective intelligence to process information of a strategic nature. This implies an evolution in the ways they relate with others: acceptance of uncertainty, tolerance of and benevolence towards new ideas.

Human resources adapting to these new challenges and to more years of professional activity, life-long training (*e-learning*), capitalising knowledge and transmitting skills, operator autonomy, knowledge of foreign languages, and involvement in the development of the company are all topics central to the process.

With the necessary flexibility, but also with the increasing complexity of products and the associated services, the machines of the future will increasingly have to interact and cooperate with the operator. Robots will be collaborative (working together and without physical barriers between people and robots *via* intuitive interfaces), and may even play a role in multiplying human strength, as is the case with cobotics and exoskeletons.

The challenge for the Industry of the Future is to offer a model in which operators act and take initiatives on a robotic production line, a little like a video game. The mechanical object, at the level of the production line which extends from design to manufacturing and distribution, becomes an adjustable object that the operator handles in accordance with changing and developing customer demand, and can simulate these options beforehand on virtual models. This requires reappraisal, the destruction of jobs to create other more qualified jobs, to invent new professions, and make ingenuity rhyme with flexibility. This also implies a major overhaul of the regulations on safety at work.

People, central to the Industry of the Future, will follow the changes in customer demand, which involves careful attention to initial training requirements but also to training throughout their careers. Products and processes will change steadily and increasingly quickly, resulting in a need for growing responsiveness and continuous training.

See the fact sheets: "Integrating the human factor"; "New knowledge and skills management tools"; "New management and empowerment tools".

Developing Corporate Social Responsibility (CSR)

CSR is an essential feature of company management and represents a major area for corporate competitiveness. The Industry of the Future must integrate the general principles of ISO 26000 (accountability, transparency, ethical behaviour, recognition of stakeholders' interests, respect for the principle of legality, consideration of international standards of behaviour and respect for human rights).

For mechanical engineering companies, a guide entitled "CSR: an approach to serve the strategy and efficiency of mechanical engineering SMEs" (normative guide NF FD E 01-001) proposes an approach based on continuous improvement, through a company project whose objective is to strengthen competitiveness and anticipate market trends. The Industry of the Future is therefore part of this overall approach to organisational progress.

See the fact sheet:
"Monitoring, foresight and economic intelligence"

The role of stakeholders

With the Industry of the Future, recent stakeholders (citizens, members of social networks and NGOs) equally as legitimate as the traditional stakeholders (public authorities, trade unions and employers' organisations, etc.) come within the circle of key players in production systems. We must invent and build the ways in which all of these stakeholders with their different approaches and cultures can interact.

The factory in the city

More integrated, more connected, more economically competitive, rooted in its region but open to the world, close to the stakeholders of its ecosystem, the Industry of Future will help to boost its network and the local economy.

Taking into account the criteria of acceptability by citizens, setting up or maintaining a plant near their homes is essential in order to limit staff travel and thus reduce the environmental impact, as well as limit the needs for transport networks and the related public investments.

New technical solutions to reduce the noise of industrial activities in terms of production, handling and logistics flows (clean vehicles, etc.), control of waste and the use of clean and safe production technologies will make it possible to consider bringing factories closer to residential areas, at least in some of the cases. Building architectures favouring integration into the urban landscape (architectural design, compact plants with low visual impact) will help to harmoniously insert the industrial site into its local ecosystem.

THE LEVERS OF COMPETITIVENESS AND THE REPOSITORY FOR THE INDUSTRY OF THE FUTURE

In the preceding chapters, the concept of Industry of the Future, the issues involved and the means with which to address them have been explained. The means in question are available as components described in the fact sheets in the second part of this guide, forming a toolbox in which everyone can find the items needed to start and effectively maintain the transition.

The components of the toolbox, each covered by an explanatory fact sheet (see part 2), are then broken down into smaller, more pragmatic subjects. If we take the example of the fact sheet "Digital command-control systems", this component includes "Numerical control", "PLC (*Programmable Logic Controller*)", "DCS (*Distributed Control System*)" and "DCCS (digital command-control system)".

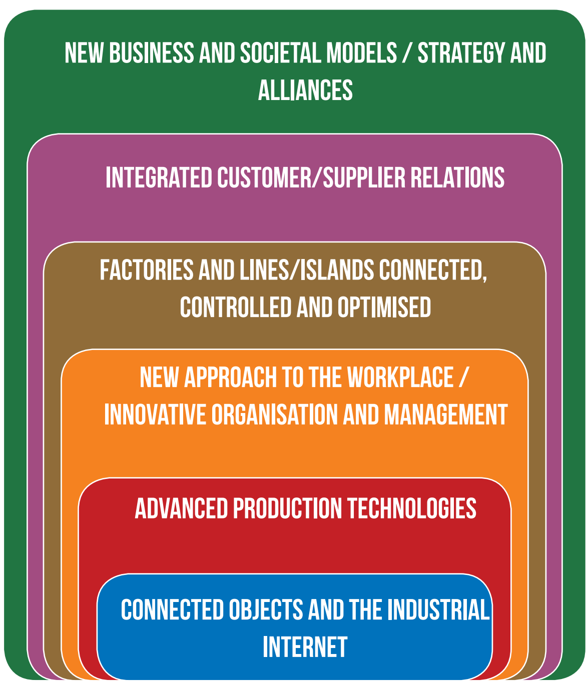
These subjects form the basic technological and organisational bricks, and the components (explained in the fact sheets) form the macro-bricks of the Industry of the Future.

The set of macro-bricks forms a model of the Industry of the Future and becomes a repository to help companies in their initiatives.

The levers of competitiveness

The macro-bricks are arranged by logical course of action in order to structure the transition process towards the Industry of the Future. They are real levers of competitiveness that fit together from the lowest level (the components of the production tool) to the highest level (the positioning of the company on the markets), including utilising a company's greatest capital: the men and women within it.

The Industry of the Future model can therefore be represented by the following diagram:



This distribution of the components, or technological and organisational macro-bricks, can be used to properly visualise them and facilitate the construction of a global transition plan for the company that is both logical and spread over several years.

Connected objects and the Industrial Internet

Here we are at the level of the field networks in the workshop. There are connected objects (for example, sensors on equipment so that they can interact with each other, and interact with the product). It is necessary to have information transmission media between these devices and here, cybersecurity is central to the problems involved in protecting against malice. It is absolutely necessary to protect a company against malicious persons who, *via* a simple smartphone, can make a direct attack on the control parameters of the company's production and affect the quality or safety of its products.

These are technologies that make it possible to connect products with each other, with machines, or even between the machines, all thanks to secure infrastructures.

They include, for example, stand-alone communicating sensors (RFID), acquisition cards to collect physical data such as noise, temperature, spindle power, torque, etc. Industrial networks can carry information captured at the "field" level to make it available to higher levels. This provides input for big data.

Advanced production technologies

These are processes and materials that are on the cutting edge of technology and are eco-responsible. They include, for example, very high performance steels, bio-sourced materials, additive manufacturing, clean and energy-efficient processes, robotics, multifunction machines, and so on.

These new generations of equipment will considerably strengthen the adaptability of productive equipment.

New approach to the workplace / innovative organisation and management

First of all, digital technologies do away with paper and provide operators with multiple forms of information enabling them to monitor and optimise a process. In addition, items of equipment assist operators, and even free them from repetitive and dangerous movements. Operators will thus be able to focus all of their availability on cognitive and high-added-value tasks. Operators can be trained continuously and their versatility enhanced by augmented reality tools, for example. Note that all this will have a major impact on organisations and management methods. The company will need more facilitators than foremen in the future.

The Industry of the Future uses the cognitive abilities of men and women: their intelligence, their ability to interpret complex situations and to define appropriate response strategies. People will be more supervisors than operators, using machine for tasks requiring strength that are repeatable, long and painful.

They will be assisted by mobile applications that provide information on the state of operation and performance of equipment to guide them in their work. They will thus develop their self-sufficiency and versatility.

Factories and lines/islands connected, controlled and optimised

Islands, lines and plants will be connected, optimised and controlled by avoiding linear organisations and silo mentalities.

In the Industry of the Future, linear processes with design/simulation, then industrialisation/ production, then maintenance/improvement will disappear. Tomorrow, even before we have created the least material element of a production line, we shall have completely designed, qualified, tested and optimised it, and trained the operators to use it.

The routing of parts in the workshop will be increasingly automated to become fluid and flexible. The back-and-forth between the physical and digital worlds will multiply and intermingle.

The development of products will be optimised by the display of 3D prototypes directly on the production line.

Even today, information is collected in the field and then analysed in real time to act directly on the process or input the operator's decision support system.

When a deviation is detected, corrective information is directly transmitted to the equipment causing the problem, whether in the plant or at the supplier's premises.

All this will completely change relationships in the workplace and the modes of supervising workshops.

Integrated customer/supplier relations

The Industry of the Future will be designed to work as a network, from supplier to customer, allowing companies to easily restructure their value chain in order to adapt to market trends and technological developments and provide a flexible, reconfigurable production tool. It will be necessary to use specific technologies mainly in the digital domain. The customer can be invited to help design products and to issue production orders and the supplier automatically receives orders and scheduled delivery dates based on orders received from the end-customer. Flows across the entire supply chain will be scheduled on the basis of orders, an increasing part of which will be over the Internet. We will need to learn to work as co-beneficiaries, in collaborative mode, and intellectual property will need to be controlled on the same basis.

The customer is thus at the same time buyer, designer and creator. The term sometimes used is that of *producers*. From their e-phone they can design a product that is customised for their own purposes, place the order and thus generate its manufacture in a pull system that they can follow until delivery.

New economic and societal models/strategies and alliances

Corporate social responsibility is one of the components of implementing sustainable development. It characterises an organisation's desire to integrate environmental and societal considerations into its strategy in order to be able to respond to the impacts of its activities and decisions on the environment and society.

An industrial tool and a supply chain, even if they are cutting-edge and very well organised, will only create value if they serve an identified use, demand and need. For this reason, any strategic thinking must be based on a broader vision that crosses the demands of customers, society, its partners and mobilisable financial capacities. Aspects as broad as the following will be addressed:

- foresight;
- future value chains and offerings;
- new business models;
- marketing and strategic breakthroughs;
- investment capacity;
- technological or geographical alliances;
- internationalisation and development of exports;
- portfolio of solutions, markets, regions and partners;
- agile and extended enterprise.

The repository for the Industry of the Future

We have seen that in order to address these various issues, a set of technological and organisational macro-bricks, forming six levers of competitiveness, is in fact a toolbox to help companies gain access to the Industry of the Future.

The package "Competitive levers / themes / macro-bricks" (themes are introduced to facilitate the classification of macro-bricks of a similar nature) is the repository for the Industry of the Future.

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FACT SHEET 7

AUTONOMOUS AND COMMUNICATING SENSORS

DESCRIPTION/DEFINITION

Autonomous sensors power themselves by harvesting energy available in the environment (solar, vibrational, thermal energy, etc.). They wirelessly transmit the information to other sensors or to a processing unit.

Low power consumption is vital to guarantee the energy balance given the low energy levels harvested. This means giving priority to:

- a simple architecture;
- integrated low-consumption electronics;
- calculation and communication loops that are optimised and reduced to the strict minimum;
- local processing of the collected data to extract relevant information and minimise communication.

Autonomous sensors must have encrypted and secure protocols. They often use latest-generation materials: shape-memory materials, electroactive polymers, etc. Users obviously expect them to be reliable and competitively priced.

Main applications of autonomous sensors:

- monitoring environmental variables;
- dynamic mapping of the variations of variables;
- optimisation of intelligent production networks and systems, integrated set of products;
- detection of system core failures.

Main types of sensors and measurements concerned:

- sensors of load, torque, pressure, temperature, displacement, level, concentration, vibration, etc.

ISSUES (BENFITS)

In economic terms

- They facilitate the transition towards more intelligent production systems without necessarily requiring large investments.
- The functioning of the communication systems and networks is optimised, therefore the gains in terms of savings and environmental sustainability are substantial.
- The energy bill is net zero.

In technological terms

- All or part of the information collected can be processed locally.
- Digital machines and automatic control systems can adapt to their true environmental and operating conditions.
- Virtual sensors can be created and allow the optimisation of the amount of information extracted from a given network of sensors (a virtual sensor behaves like and replaces – for the user – a complete network of real sensors).

In terms of business transformation

- Complying with regulatory requirements and existing policies, autonomous and communicating sensors render networks and systems intelligent through the gradual deployment of information and communication technologies.
- They can help to integrate a true information culture and grasp the complexity of processing and capitalising on these large data repositories.

FACT SHEET 7

AUTONOMOUS AND COMMUNICATING SENSORS

In environmental and societal terms

- Autonomous and communicating sensors are tools that enable operators to monitor and diagnose problems, to prioritise and manage maintenance operations, continuously and remotely, and to use the collected data to optimise all performance aspects of the production system or the product (and its uses).
- They can provide consumers with the information and tools they need to adapt their behaviour, the way they consume and their practices.

KEYS TO SUCCESS

In technological terms

- Miniaturisation and performance of energy converters.
- Specific miniaturised batteries designed for extreme conditions.
- Integration in materials, films and coatings.
- Mechanical, electrical, electronic and software integration.

In digital terms

- Near real-time computer processing.
- Challenges concerning the volumes of data requiring additional processing, storage and administration functions.

In terms of skills to be mobilised, knowledge and training

- The skills to master are those relating to automation, information technology, electronics and radio protocols, particularly for the efficient use of autonomous and communicating sensors and their maintenance or replacement in the event of malfunctioning.
- Additional knowledge in materials and energy conversion will enhance the analysis of potential degraded operating situations.

Questions to ask

- What frequency of data communication is really necessary?
- What frequency of data recording is necessary?
- What is the required power autonomy of the system (from a few hours to several decades) with optimised energy consumption?
- Define the conditions of use of the communicating product (service life, data rate, range, data volume).

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	**Frequent**	Pervasive

FACT SHEET 11

MACHINE COMMUNICATION AND AGILITY

DESCRIPTION/DEFINITION

The Industry of the Future concept (still called Industry 4.0 in Germany) corresponds to the adaptation of industrial processes *through* the setting up of *smart factories* capable of greater production adaptability and more efficient allocation of resources, thereby paving the way for a new industrial evolution.

The Industry of the Future aims at increasing the agility of businesses and producing specific and customised products at series production prices. The transformation of industrial sites into connected factories requires the creation of communicating production tools. It reduces the communication steps between the customer demand and the setting up of production lines to meet that demand.

The Industry of the Future is not just about robotisation; it also concerns product differentiation. It does not result solely from the digitisation of information with the development of technologies such as connected objects (Internet of Things), virtual or augmented reality, cloud computing and big data. It responds first and foremost to the challenges of the VUCA (volatile, uncertain, complex and ambiguous) world and changes in consumer behaviour.

Industry must be intelligent, agile and innovative to make its production methods evolve thanks to technologies that supplement and assist human work (collaborative robot applications – emerging industrial robotics technologies) and reduce industrial accidents caused by process failures. Human-machine interfaces (HMI) can use sensors, robots, wireless systems, software and machine-to-machine (M2M) communication to collect and analyse data. These data can be used to manage operations or to interconnect production sites with the robotic systems of the factory, the back-office of the company, its partners and suppliers, throughout the logistic chain.

ISSUES (BENEFITS)

In economic terms

The prime objective of automation and integrated intelligence is to reduce the number of human interactions while at the same time increasing their quality, to guarantee shorter response times. The development of artificial intelligence in industry can lead to a reduction in the number of human-machine interfaces, while giving them greater importance when the machines necessitate human intervention. In an intelligent system, a regular production flow requires no monitoring by humans. It is when a machine anticipates or detects an anomaly that it cannot correct that human intervention and decision-making are necessary.

- Improve quality control, reduce downtimes, increase the speed and efficiency of industrial processes.
- Enable decisions to be made in real time within factory processes.
  - > Alerting to critical defects in the quality of assembly that are not visible to the human eye.

In technological terms

An industrial HMI must be robust, reliable and resistant, especially when the operators work in noisy, dusty, damp and dimly lit environments. In the connected factory where human intervention essentially comes down to making strategic decisions, data presentation is a very important aspect of the design. It must not be limited to displays and touch screens. It must also integrate augmented reality, speech recognition and voice synthesis, and intuitive data visualisation. In the fields of maintenance and repair, augmented reality glasses will play an important role in the sense that they will show the impact of the data delivered by the sensors and transmit them to the technician so that he or she can rapidly solve the problem. The data could be streamed live through visual displays that facilitate understanding.

FACT SHEET 11

MACHINE COMMUNICATION AND AGILITY

In terms of business transformation

- The possibility of adapting production to demand: the production means must adapt to demands that can vary as much in the quantity as in the form of a product. The means of production and the supply chain as a whole must become agile in order to react rapidly to market changes.
- Customisation of production: large production series are becoming rarer and manufacturers have to manage an increasingly complex portfolio of products with ever-shorter industrialisation time frames and budgets. This necessitates more effective production means (efficiency, fewer defects, fewer failures) with accelerated learning. The sharing of information with machines through the digitisation of data is one lever.
- Process flexibility (agility): a company's internal processes must be able to respond rapidly to changes (life cycle of the item, supply chain, subcontracting and partnership, collaborative process). The information system must be able to adapt to facilitate and carry these changes.
- Traceability: this is a major issue, whether for reasons of quality, regulations, customer service or market protection. Traceability can be divided into two concepts: track and trace.
  > *Tracking* (logistical traceability): this corresponds to quantitative control. It is used to locate the products and determine their destinations and origins.
  > *Tracing* (product traceability): this allows qualitative reconstruction of the product paths. It is used to determine the causes of a quality problem.
- Corporate and management culture: Implementing the Industry 4.0 process completely disrupts the corporate culture, which must be considered to be its cornerstone. It consists in reorienting the company as a whole towards the customer, thereby changing from a supply-oriented approach to a demand-oriented approach. It breaks down the company silos, resulting in more cross-functionality, more collaboration and greater agility. It has a multitude of impacts on work organisation and on the workers and their skills (decentralisation of decisions, modified work environment, development of new digital skills, capitalisation and sharing of knowledge, etc.).

► KEYS TO SUCCESS

In technological terms

- Securely connect the industrial machines to the Internet and facilitate remote access and the collection of a wide range of information produced by the industrial machines.
  > Remove the barriers that separate industrial applications and computing standards.
- Provide their connected machines with artificial intelligence and give them a language with multiple applications.
- Develop cognitive industrial machines: machines capable of using the data collected by their sensors to detect, analyse, optimise and take measures in the production line.
  > Solutions capable of providing cognitive and predictive data in real time to optimise the operation and maintenance of smart grids.

In terms of skills to be mobilised, knowledge and training

- Skills in the entire data value chain, from the production, characterisation and utilisation of the data to the creation of value from them.

Questions to ask

- Define the objectives of ramping up machine intelligence and characterise the various technical milestones of the process.

FACT SHEET 11

MACHINE COMMUNICATION AND AGILITY

▸ MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 12

ELECTRONIC COMPONENTS AND SUB-SYSTEMS

DESCRIPTION/DEFINITION

Having driven the growth of numerous sectors of activity, electronics continues to play a vital role in our modern economies: transport, safety, health, aeronautics, etc. And more recently, connected objects. However, with the possibility of producing at lower cost in other countries, a large proportion of electronics production is now relocated or outsourced abroad, as is the case in particular with virtually all the assembling of large volumes of consumer electronics products. It is in Asia, and China in particular (with 50% of global production), that the majority of electronic equipment production activities are concentrated (compared with 22% for Europe). Nevertheless, thanks to an ecosystem and an end-to-end value chain (from R&D at the front end to assembly at the back end), France has become highly competitive in high-added-value electronics and now holds the lead position in the European industry of electronic components and industrial electronics.

Main applications of these technologies: the sector is characterised by a phenomenon of pervasion, namely the steadily increasing penetration of electronics into different sectors of activity.

- Space and defence: satellites, observation, launch vehicles, etc.
- Aeronautics: avionics, guidance systems.
- Automobile: connected vehicles, electric vehicles.
- Telecommunications: R&D on 5G networks and the deployment of fibre-optic networks (FTTH - fibre-to-the-home).
- Medical: eye surgery, ultrasonography, lab-on-chip, implants, micropumps, medical devices.
- Consumer goods: telephony, computers, tablets, geolocation systems.
- Industry: special machines, automatic control systems, robotics, etc.

Main technological segments concerned:

- active components (integrated circuits, memories, microprocessors, etc.) ;
- passive components (capacitors, resistors, self-induction coils, piezoelectric components, magnetic components, etc.) ;
- radio frequency (RF) and microwave components;
- connectors;
- cabled cords;
- printed circuits;
- plastronics - printed electronics;
- electromechanical components (relays, switches, keyboards, etc.) ;
- sensors (remote contacts);
- oscillators (quartz, etc.) ;
- microelectromechanical systems (MEMS);
- hybrid units;
- LTCC, HTCC (Low and High-Temperature Cofired Ceramics), SSI (Small-Scale Integration).

ISSUES (BENEFITS)

In economic terms

- Highly globalised sector: the European and French companies in the sector face significant competitive pressure from emerging markets in terms of production and labour costs. There is a strong need for innovation in order to remain competitive.
- Between 2008 and 2016, the value of the electronics production market almost doubled, rising from 1,140 billion euros to 2,000 billion euros. All the players in the sector displayed a growth in activity of 3 to 5% on average, sometimes higher (+20% in S/C).
- The gain in competitiveness is already allowing the repatriation of previously outsourced production, including on large series and markets with strong potential such as the automotive market.

FACT SHEET 12

ELECTRONIC COMPONENTS AND SUB-SYSTEMS

In technological terms

- Decades-long race for innovation focusing on the miniaturisation of electronic components and sub-systems to integrate more transistors and functions on a given circuit.
- "More-than-Moore" or "Beyond-Moore" strategy.
- New methods of cooling electronic components to reduce their energy consumption while increasing their service life.
- Increased resistance to magnetic interference (electromagnetic compatibility - EMC). Strict compliance with environmental regulations (REACH, RoHS).

In terms of business transformation

- A high degree of adaptability, production of smaller series and the need for versatility between areas of activity are sought after by the companies positioned on the professional markets.
- Nanometric scale, increased robotisation, necessity for "clean room" manufacturing and very short life cycles leading to rapid obsolescence, obliging the players to adapt.

In environmental and societal terms

- Increase in the geographic specialisation of electronics production on a planetary scale (China accounts for 50% of the world's production).
- The emerging markets, which currently constitute the largest centres of growth, are becoming increasingly equipped.
- New technologies to reduce the energy and environmental footprints of the production of electronic components and sub-systems.
- New processes for treating and recycling critical rare earths and metals.

KEYS TO SUCCESS

In technological terms

- Acceleration of the pace of innovation due to the increased demands for gains in productivity.
- Gradual integration of electronic components in embedded systems with severe environmental constraints.
- Technological challenges with regard to energy consumption, data security, accessibility from anywhere, reliability.
- Innovations in the materials and architectures which will enhance the performance of integrated circuits and other components (capacitors, PCBs, connectors, etc.).

In digital terms

- Management of thousands of part numbers in real time, management of the automation and utilisation of data within digitised and factory-of-the-future-oriented production plants.
- Collaborative robot (Cobot) and autonomous (self-driving) vehicle projects, which will ultimately be able to provide input for surface-mounted component (SMC) placement machines, and exoskeletons to reduce the physical efforts of production operators.
- Data confidentiality, connectivity (data rates).

In terms of skills to be mobilised, knowledge and training

- Shortage of labour in certain electronics sectors: analogue and HF electronics (power electronics in particular) and electromagnetism, for example.
- Difficulty in finding specialist technicians with intermediate qualifications: design technicians; development technicians; test technicians; industrialisation process engineering technicians in electronic manufacturing; testing and validation technicians.

FACT SHEET 12

ELECTRONIC COMPONENTS AND SUB-SYSTEMS

- Shortage of candidates on the labour market for training as automated electronics production machine operators.
- Required skills not fully met in the activities of electronics wiring technician, printed circuit boards and prototypes.
- Convergence of skills in mechanics, electronics and software, often with a high level of commitment, which implies having multi-skilled project managers.

Questions to ask

- Additive manufacturing penetration rate for ultra-fast prototyping of professional printed circuits.
- Expanded use of electronic components in new sectors in response to new economic and societal needs, which more specifically require real-time information management and the use of RFID chips or microcontrollers: security (surveillance systems, cybersecurity), energy efficiency, which affects several sectors such as the automotive industry (electric vehicles) or domotics (energy management and regulation) and telehealth (domestic medicalisation aid systems).

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	**Frequent**	Pervasive

FACT SHEET 17

CYBERSECURITY

DESCRIPTION/DEFINITION

Cybersecurity consists in ensuring that the digital resources of a company, whether hardware (e.g. chip, mainframe computer, PC, robots, numerical control machines), software (e.g. programs and data) or communication (e.g. Wi-Fi, Internet), are protected against any attack that would divert them from their initially planned function.

It aims at ensuring for the tools, services and data:

- availability (e.g. operators have access to their machines when they need them, including when their operation and/or the conditions of use are degraded);
- integrity, that is to say conformity of the characteristics with the requirements. (e.g. the machine carries out the requested action and that action only, including with degraded operation in case of an attack);
- confidentiality of access (e.g. customers' data remain confidential under all circumstances).

Meeting these three requirements increases the level of security of employees/partners/customers of the goods/tools/production means and optimises the functioning of the company.

Cybersecurity fits into a wider company reflection on safety, and focuses more particularly on:

- the industrial systems (workshops, machines, platforms, SCADA (Supervisory Control and Data Acquisition), premises, etc.) ;
- the information systems (software, servers, means of communication);
- the products and services proposed to customers.

Each of the digital interfaces necessary for communication between these various constituents of the company represents an additional risk.

ISSUES (BENEFITS)

In economic terms

- Protect the company data and its intangible heritage.
- Render secure the relations with suppliers and subcontractors.
- Provide secure connected products and/or connected services.

In technological terms

- Guarantee the functioning of the workshop and the means of production.
The tools for the digital transformation of the workshop and its production means (IoT, cloud, smart machines, M2M communications, robots, etc.) are all sources of cyber risks because they create new vulnerabilities and new threats. Yet even workshops that are not connected to the Internet are exposed to digital threats (e.g. contaminated USB stick plugged into production equipment for maintenance or data transfer purposes). As for factories that start to modernise their equipment by integrating digitised tools (e.g. retrofitting machines with the incorporation of digital capabilities), they are no doubt the most vulnerable because they use systems and means developed without integrating security concepts.

In terms of business transformation

- Heighten awareness, train and guide the personnel.
The human factor is the main source of the cybersecurity risk. The threats often exploit individual behaviour (use of USB sticks, Internet links, opening e-mails from unknown sources, etc.), rather than software deficiencies to install malware, steal confidential information, transfer funds, etc. The risks of being taken in by malicious messages are all the greater when they imitate authentic messages very faithfully. This risk is amplified with the widespread use of mobile devices. The boundaries between personal and professional spaces are becoming less and less clear-cut,

thereby considerably increasing the vulnerabilities. Even when used in a strictly professional context, these devices introduce new security issues and therefore necessitate the implementation of appropriate measures. The risk borne by the human factor concerns all the employees in a company (computer engineers, automation engineers, administrative personnel, workshop personnel).

KEYS TO SUCCESS

In order to be able to protect the company (employees, production system, information systems) against attacks of all types – whatever the size of the company and the degree of integration of digital tools and exposure to the Internet – it is vital to establish a security policy that is adapted to its environment and industrial context. Consequently, the five measures that are essential to the integration of cybersecurity into the company are described below:

- put in place a digital security procedure that involves everyone in the company;
- describe the cybersecurity of the company in relation to cybersecurity in general and formalise a plan of action;
- implement the plan of action and check its effectiveness;
- if necessary, use service providers or trustworthy solutions;
- follow the legislation and respond to the tightening of regulations.

In technological terms

- Guarantee operation of the machines.
  A production worship comprises a multitude of transformation, handling and peripheral machines. These machines are increasingly numerically controlled (e.g. programming via human-machine interfaces), instrumented (e.g. sensors that can measure and use the collected data for predictive maintenance purposes), connected and communicating, through either M2M (machine-to-machine) networks or the IoT. Finally, all the machines and robots are directly or indirectly connected to networks, and to the Internet in particular. These machines can often accommodate USB sticks or maintenance consoles. It is therefore necessary to protect them. And their security cannot be limited to software and hardware solutions which aim to identify and eradicate malicious code. It must also guarantee the reliability of integrated information transfer between the different machines.

- Control access.
  Unfortunately, the Internet connection is not the only potential vector of malicious attacks or even negligence. A straightforward, readily accessible USB port can become the entry point for a cyber-attack. Yet a large number of workers need to have physical access to the facilities. Appropriate measures must therefore be put in place to control the physical access points that would permit entry into the system. They concern in particular all computing equipment, sensitive workshops or parts of workshops, archive rooms, etc.

- Protect the connected products and services.
  Connected objects have become ubiquitous and are becoming increasingly exposed to cybersecurity-related risks. Selling connected products or associated services therefore requires the implementation of security measures to protect the company, its customers and third parties. The implementation of these measures is

FACT SHEET 17

CYBERSECURITY

made complex by the diversity of protocols used. The harmonisation and standardisation of these protocols is therefore a real issue. A number of criteria and certifications have recently been put in place in France to establish a security framework for connected objects.

In digital terms

- Controlling the management and exchange of internal digital data.
  Conventionally, the management and exchange of internal digital data concerns management computing at all company levels. With the advent of the Industrial Internet of Things (digitisation and connection of machines and production components), the internal data naturally spread to sources situated on the production line, including infrastructure for example.

- Protecting production traceability.
  Industrial systems are making increasing use of embedded digital means to ensure production traceability, either to have a record of production history or to be able to identify the state of product transformation at any time. These tracking means can be placed on supports (or pallets) or directly on the product. The most commonly used means are optical character recognition (OCR) and barcodes.

- Saving and protecting data and software.
  An increasingly large amount of information exists in electronic format and contributes extensively to the value of a company. It is therefore vital to save and protect this information against all forms of data loss or possible attacks to preserve the integrity and confidentiality of the corporate data. Saving necessitates particular precautions, firstly to avoid inducing leakages of confidential information, and secondly to guarantee the availability of the data, even in case of failure, which implies having a frequently applied and secured archiving process.

- Making good use of online services and the cloud.
  Using online services consisting in making remote use – usually via the Internet – of functions such as storage, calculation or services in general (e-mail, document sharing, project management, etc.) has become common practice in personal and professional spheres. These services allow full benefit to be drawn from the advantages of the digital revolution (anyone can have access to services which previously required substantial investment) and constitute a powerful competitiveness lever in often-neglected costs and functions. A number of precautions must however be taken to fully capitalise on this potential without undermining the security of the installation. The proportion of online services that are internalised (on servers hosted and operated by the company) or not (on learning servers operated by another company) depends on the company's constraints and own specific strategy.

- Protecting digital data with respect to the exterior
  The dematerialisation of contracts requires appropriate means of protection such as electronic signatures with legal value. The archiving of electronic accounting and financial documents must moreover comply with the standards in effect (AFNOR NF Z 42-013 or ISO 14641-1).

In terms of skills to be mobilised, knowledge and training

- Heightening employee awareness.
  Digital aspects are predominant in the Industry of the Future, but machine digitisation and connectivity give rise to new dangers that must be guarded against. A large proportion of incidents associated with cybersecurity result from employees' lack of knowledge of the risks to which the facilities are exposed. Employee awareness of good practices therefore helps reduce vulnerabilities to, and opportunities for, attacks. As the risks are changing constantly, awareness-raising measures must be taken regularly.

FACT SHEET 17

CYBERSECURITY

- Breaking down barriers between the different departments (between the computer system and the industrial systems in particular).
  It is not uncommon in SMEs to see the cohabitation of different worlds associated firstly with management computing and secondly with industrial computing or even automation. Conducting a successful cybersecurity communication campaign necessitates the building of a common language. To achieve this, the different worlds of the digital sphere must become decompartmentalised.

- Using mobile devices for remote access.
  The Industry of the Future is underpinned by the real-time provision and utilisation of information to make decisions, or even to act on the information system or on a component of the production means. Remote access, whether to manage production operations or for remote maintenance purposes, relies on mobile devices such as smartphones, laptop computers or tablets. These means are usually provided by the companies, but we are starting to see personal mobile devices being put to professional use. The major risks of intrusion and malicious acts lie essentially in two potential vulnerabilities, namely connection and loss or theft.

- Communicating via social networks, electronic messaging, the Internet.
  The visibility and the economic development of companies, and their attractiveness regarding work methods, particularly for digital natives, are based on massive utilisation of the Internet, electronic messaging and social networks, whether global (Facebook, Twitter) or private, limited to the bounds of the company. This multiplication of digital communication tools in the office and factory, combined with the growing use of professional messaging tools for personal purposes, results in an explosion of cyber risks in the workplace.

Questions to ask

- What will be the impacts of the European General Data Protection Regulation (GDPR), which shall be applicable as of 2018 to all companies collecting and processing personal data?
- A security policy should be built around three major questions:
- What must I protect as a priority? What is my information heritage?
- What are the risks incurred (external, internal)?
- What are the risk-aggravating factors?
- Once these factors have been determined, the security policy must establish a minimum level of security that will lastingly protect the entity.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 23

OPEN ENVIRONMENT

DESCRIPTION/DEFINITION

If companies want to benefit from the plethora of data generated by their connected industrial assets, the information must be able to circulate without hindrance and generally in real time, irrespective of where the analysis software applications have been implemented, be it on the network periphery or in the cloud.

Interoperability is one of the major challenges facing the Industry of the Future. To optimise the operations of the factory and its insertion into the value chain, its systems are compatible with information exchange standards and can use digital services in the cloud (computing, optimisation, modelling services, etc.). The factory manages the interoperability of its industrial systems and stores its data in a unique database and in the cloud.

Often designated by their abbreviations, machine-to-machine (M2M) and the Internet of Things (IoT) are two very similar concepts, often a source of innovation in services. An IoT/M2M system is complex: the object/the sensor, the radiofrequency communication networks, a gateway/a router which connect to the Internet via central systems (cloud servers) to offer service.

Tomorrow the flexibility of architectures and data streams will offer interactions between the objects that will go beyond their manufacturers or sectors of activity, in order to provide new, higher-performance services: interoperability is in motion. To optimise the time to market, the Internet of Things (IoT) platforms – whose purpose is to connect these heterogeneous devices and make them communicate with one another – are multiplying.

These increasingly complex technologies necessitate a good overall vision of the various system constituents, such as the software architecture, the protocols, the cloud, the big data, the security and the networks, as well as the object.

Making production flexible, which is one of the main end-purposes of the Industry of the Future, requires total interoperability of the facilities within the factory and therefore the implementation of a single standard for communication between machines and with the information systems. Interconnection is becoming an absolute necessity to enable the organisation to achieve greater efficiency. The OPC UA (Open Platform Communications Unified Architecture) exchange protocol is now increasingly establishing itself on the "high-level" layer (ERP - Enterprise Resource Planning, MES - Manufacturing Execution System, PLC - Programmable Logic Controller, DCS - Distributed Control System), etc.) as a global interoperability standard between the machines and the systems. With regard to the "low-level" layer (sensors, actuators), IO LINK is becoming a de facto standard. Virtually all the manufacturers have implemented OPC UA and IO LINK directly in their products and solutions, which greatly facilitates interoperability of the machines and equipment.

ISSUES (BENEFITS)

In economic terms

The aim is to use the data to pinpoint wastage, and to do so in all areas. By having better knowledge of the production tool, it will be possible to reduce waiting times between machines, for example.

- Improve the quality of companies' products and services, gain production flexibility and increase employees' skills.
- Enable the different sites to benefit from joint management of customer files and commercial information, harmonise the action to take.

In technological terms

- A communication protocol architecture that allows the opening of data and the interoperability of hardware and software.
- Databases hosted remotely in a cloud so that data can be shared while guaranteeing their integrity.
- Give coherence to the digital transformation of the sector and ensure the interoperability of the computer systems.

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OPEN ENVIRONMENT

- Enable several links in the organisation to use a same given data item.

In terms of business transformation

Setting up of mixed State-industry standardisation bodies at the European and global level to anticipate the foreign standards and those of the web giants, which will be increasingly present in the industries of the future.

▸ KEYS TO SUCCESS

In technological terms

- Using the communications standards of the factory of the future (OPC UA, IO LINK, etc.) :
  - > utilisation of a common language and communication protocol between service-oriented machines.
- Collecting and routing the data to the processing devices.
- Building a quality process to identify and correct abnormal data.

In digital terms

- An overall digital culture that allows the adoption of a veritable coherence integrating all the company's activities, from raw materials procurement to user feedback.
- Taking into account the new regulations, particularly the European GDPR law, which will oblige the market to eliminate cyber-attacks so that no data are compromised.

In terms of skills to be mobilised, knowledge and training

To overcome the incompatibilities of network protocols, the OPC Foundation has been working since 2003 on a unified architecture overlay baptised OPC UA (open platform communication unified architecture). This platform enables heterogeneous industrial systems to communicate with one another by sending messages following a client/server structure.

Questions to ask

- What are the main data that can be used in the production systems?
  - > Process data, corresponding to the information collected by the equipment during product manufacture.
    - Temperature, pressure, flow rates, raw material dosing, etc.
  - > Condition monitoring data which indicate the status of the production means when the product is manufactured.
    - Information on the diagnosis of motors, actuators, electronic boards, network switches, PLC central processors, etc.

▸ MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

▸ USEFUL LINKS

Protocol websites: OPC Foundation, IO Link
Contributors: Cetim, Gimélec

FACT SHEET 36

INDUSTRIAL INTERNET

DESCRIPTION/DEFINITION

The Industrial Internet of Things (IIoT) represents a bidirectional connection of industrial objects (PLCs, data acquisition and control systems, data historian, etc.) with computer systems, generally hosted in the cloud, in order to automatically monitor, control and optimise the operational physical processes of factories.

The technological progress of the industrial sector has enabled the transition from manual production to mass production through manufacturing and assembly lines and then, thanks to computers, to factory automation. With the constant development of work methods, production sites are gradually being transformed into smart factories, a concept that is also called "Industry of the Future".

Thanks to the Industrial Internet of Things, computer systems monitor and control the physical processes, then deliver the collected data to dashboards supervised by operators. It is a question of optimising costs, tracking object life cycles in order to ensure lean industrial maintenance management under optimum conditions of safety, or to collect data in order to better design the next generation of products. Combined with artificial intelligence, connected industrial objects help improve profit margins.

According to Research Nester, the global IoT market (industrial and general public) should increase from close to 600 billion dollars in 2015 to 724 billion dollars in 2023. Similarly, the consultancy Markets & Markets forecasts growth from 130 billion dollars in 2015 to 883 billion in 2022, with annual growth averaging 32.4 % between 2016 and 2022. IIoT is a vector for global growth that could increase our GDP (gross domestic product) by 4 to 5 percentage points over the next ten years.

ISSUES (BENEFITS)

In economic terms

- Improve industrial performance thanks to the monitoring, inspection and optimisation functions, and to the autonomy of connected industrial objects.
- Increase operational effectiveness, better manage the risks and standards.
- Create new economic models based on new sources of revenues through on-demand usage and usage-based billing, for example. These two processes will reduce the costs of ownership and the return on equipment investment.
- Improve the analysis of quality, optimise the organisation of workshops and production lines, reduce discards and predict malfunctions and potential failures through predictive maintenance aids thanks to the coupling of industrial data with analytical tools.

In technological terms

- The Industrial Internet of Things integrates what are referred to as advanced analytical tools, by executing advanced scientific algorithms such as machine learning, predictive analysis models and others. It also uses the data thanks to sensors and machine-to-machine connection (M2M: communication between machines without human intervention), which has existed in the industrial sector for years. IIoT changes the situation in that it facilitates the collection and processing of large quantities of industrial information, not only in a factory but also between several production sites, through the cloud in order to consolidate and summarise the inter-site data in the dashboards (or industrial cockpits). Sensors measure information such as the electric signal entering a device or pressure parameters. Information which, when combined with advanced analytical techniques, can be used to determine whether a component of an item of equipment is functioning correctly and under optimum conditions.

FACT SHEET 36

INDUSTRIAL INTERNET

In terms of business transformation

A digital ecosystem must integrate process industrialisation from the product design stage. Agile methods, which meet the time-to-market requirements, rarely equate well with security. The absence of standards in this area and the need to secure the ecosystem from end to end, that is to say from the object to the user, are aspects which must not be neglected.

Manufacturers have been in possession of their factories' sensitive data for a long time already, but these data are often stored in monolithic management applications which have contributed to the creation of multiple silos, rendering decision-making difficult, if not impossible, because it is based on partial, non-holistic data.

In environmental and societal terms

- Reduce the risks in hostile working environments.
- Anticipate potential malfunctions of machines and processes to gain in efficiency.

KEYS TO SUCCESS

In technological and digital terms

The Industry of the Future uses cyber-physical systems[1] to create networks in which the connected peripherals can exchange with one another. The innovation brought by the IIoT creates new areas such as telemetry in which semi-autonomous machines can be remotely controlled by humans via a virtual interface. IIoT enables manufacturers to use tele-robots to carry out tasks in hazardous environments, such as the inspection of submarine pipelines, maintenance of electric lines, decommissioning of chemical plants, etc.

The Industry of the Future is based on the potential of the IIoT technologies in the manufacturing sector. By fuelling automation and the exchange of data, the Industry of the Future helps manufacturers to decentralise decision-making, check information transparency, promote technical assistance between machines and humans, and create an interoperable environment.

Questions to ask

- How can connected industrial objects be made secure?
- What platform do I choose to manage my fleet of connected industrial objects?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

1. Embedded electronic systems on which software and/or analytical execution engines are deployed.

FACT SHEET 55

WIRELESS INDUSTRIAL NETWORKS

DESCRIPTION/DEFINITION

Representing one of the facets of the Internet of Things, wireless industrial networks consist of a set of technologies and remote communication protocols that allow the exchange of data between components, between components and machines, and between components and management and control systems. Machine control and monitoring can thus be optimised on the basis of networks of wireless sensors, which can be fixed or mobile (carried on board vehicles). Wireless communication can be divided into three types:

- long-range communication (GSM/GPRS, UMTS, WiMAX, etc.) ;
- medium-range communication (WLAN, Wi-Fi, Li-Fi, by light, etc.) ;
- short-range communication between sensors (Zigbee, Bluetooth, ISA100, RFID, NFC, etc.).

The future trends concern in particular:

- the deployment by 2019 of 5G, with data rates 100 times faster than those of 4G;
- the emergence of data exchanges by light (Li-Fi). The French company OledComm proposes, for example, geolocation (GEOLiFi) and data exchange (LiFiNET) solutions that use light;
- the development of networks of communicating sensors.

ISSUES (BENEFITS)

In economic terms

- Time savings when installing wiring and connectors.
- Potential reduction in maintenance costs and modifications to the network topology.

In technological terms

- Simplicity of the installation, flexible deployment and rapidly modifiable.
- Possibility of distributing intelligence in the equipment down to component level (valve, pump, motor).
- Control of system status by self-monitoring and self-diagnosis.
- Real-time control of production lines.
- Possibility of communicating between poorly accessible, isolated or dangerous sites.
- Elimination of wires in rotating or mobile equipment (rotary collectors, etc.).
- Large-scale development of multi-component communication systems: smart grids, smart buildings, smart cities.

In terms of business transformation

- Wireless communications foster the adoption of remote collaborative processes (automated and human) and mobile processes (access to information without being physically connected to the company site).

In environmental and societal terms

- Car-to-car and car-to-x communication : improved traffic flows, reduced fuel consumption, increased safety.

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WIRELESS INDUSTRIAL NETWORKS

KEYS TO SUCCESS

In technological terms

- Stabilise the technologies, protocols and performance. Strategic choices have to be made to ensure porting and modularity (structuring of applications, interoperability, etc.).
- Enhance the reliability of communication protocols (dependability and availability, real time, self-monitoring, electromagnetic interference, communication breakdown and resumption, etc.).
- Minimise component energy consumption by using tailored or dedicated signal processing techniques, transmission and storage protocols (energy recovery, for example).
- Withstand electromagnetic interference generated by certain items of equipment.
- Withstand potentially extreme temperatures.
- Display high levels of robustness and tightness (sealing).

In digital terms

- Ensure the security of communications: monitoring of passive listening, identification of emitting objects, access control (intrusion risk).

In terms of skills to be mobilised, knowledge and training

- The information to transmit and store must be prioritised by type of application (importance of the consistency of the functional and hardware architectures).
- Adapt the data processing software to the limited storage capacity of chips and the very large volumes of information to process.

Questions to ask

- How do you develop systems that are interoperable and compatible with future standards?
- How do you choose the appropriate communication protocol? What are the needs?
- Are the levels of reliability required by the application compatible with the use of a wireless network?
  - > Information exchanges with a mobile device?
  - > Extension of an existing network?
  - > Are information exchanges being made across an inaccessible or hazardous zone or a zone with a moving environment?
  - > Ensure the mobility of the operators?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 56

TRADITIONAL INDUSTRIAL NETWORKS

DESCRIPTION/DEFINITION

Traditional industrial networks are based on point-to-point proximity communication technologies and protocols that allow the exchange of data volumes that are generally larger than with wireless technologies. These technologies are often complementary.

As Patrick Molck-Ude, Managing Director of the Telecommunications Division of T-Systems points out, "*The data traffic of corporate networks is growing constantly. In the future, companies will only be able to succeed with networks of a new design*".

ISSUES (BENEFITS)

In economic terms

- The conservation of an existing wired network may be economically beneficial. This is because the cost of developing a wireless network that is compatible with all the equipment in place can prove to be high.
- Simplicity of installation; technology that is relatively economical; a network is easier to secure when an intrusion attempt necessitates a physical connection.

In technological terms

- Wired networks can present more access difficulties for a cyber attacker than wireless networks, which implies data encryption.
- Wired networks are generally more reliable than wireless networks. Wired networks remain appropriate for control applications in which the real-time aspect is important.
- Wired networks display low sensitivity to interference.
- The volumes of data transmitted are also larger than with wireless systems.
- Wired networks do not necessitate authorisation for frequency allocation, as can be the case for wireless networks.
- Wired networks remain appropriate in certain types of structures, particularly those containing large quantities of metal which can create zones that are difficult for a wireless signal to reach.
- Wired technologies have the benefit of several decades of experience feedback.

In terms of business transformation

- Wired technologies such as fieldbus are very widely used by instrument suppliers.
- The fieldbus technology is supported by the majority of automatic control system suppliers and maintenance operators are familiar with it.

KEYS TO SUCCESS

In technological terms

- Design the architecture such that a short circuit does not affect the entire network.
- At present there is no unique standard concerning the Real-Time Ethernet (RTE), but several mutually incompatible implementations. For example, in cases where a class-C Ethernet is used, compatibility with the conventional Ethernet is abandoned in order to achieve higher performance (cycle time less than one millisecond).
- The TSN working group of the IEEE aims at improving the reliability of the real-time capacities of the standard Ethernet (IEEE 802.3, IEEE 802.1D) and is focusing its attention on the following aspects:
  > reducing latencies and improving the precision of deterministic protocols;

FACT SHEET 56

TRADITIONAL INDUSTRIAL NETWORKS

> improving error-tolerance without additional hardware;
> improving levels of dependability and security ;
> ensuring the interoperability of the solutions from different manufacturers.

In terms of skills to be mobilised, knowledge and training

- At the start of each project, determine the best technologies to implement (wired or wireless).
- The deployment of 802.11ac is not as easy as straightforward upgrading of the access points.

Questions to ask

- Do the questions of real-time operation and availability allow the implementation of a wireless network?
- How can telecommunications be included in the company's information technology (IT) strategy, that is to say create a comprehensive IT strategy that considers the external and internal communication processes as being essential operational processes?

▸ MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 1

VERY HIGH PERFORMANCE STEELS, NON-FERROUS ALLOYS AND SUPERALLOYS

DESCRIPTION/DEFINITION

High-performance steels (HPS) aim to meet weight-reduction and safety specifications while preserving their ease of use. They offer an upgraded alternative when the characteristics of conventional steels become insufficient for the targeted application. Their characteristics provide the possibility of significantly enhancing the performance of numerous highly stressed mechanical components.

High-performance non-ferrous alloys such as aluminium, magnesium and titanium alloys are materials which aim essentially at meeting weight-reduction specifications. Aluminium and titanium alloys moreover meet mechanical strength requirements. Titanium also provides corrosion resistance.

Superalloys are developed for high-temperature applications and applications requiring high corrosion and creep resistance, or greater mechanical strength under extreme conditions and/or impacts.

The main applications of very high performance steels, non-ferrous alloys and superalloys are found in:

- aeronautical structures and engines (nickel-based superalloys, aluminium-lithium alloys, titanium alloys);
- industrial gas turbines: valves, disks, post-combustion chambers;
- nuclear: valves, power transmission, pumps, heat exchangers;
- petrochemicals: nuts and bolts, valves, pump bodies;
- castings;
- packaging (aluminium alloy);
- automotive;
- medical: orthopaedic and dental prostheses.

Main technologies concerned:

- very high strength (VHS), Dual Phase, TRIP and maraging steels;
- aluminium and aluminium-lithium alloys;
- magnesium alloys;
- titanium alloys, titanium aluminides;
- solid parts in nickel- or cobalt-based superalloys;
- steel sheets for hot and semi-hot (warm) forming.

ISSUES (BENEFITS)

In economic terms

- Mastering these materials makes it possible to meet complex functional specifications while at the same time satisfying severe operating conditions in terms of vibration, corrosion or temperature. A maximum service life means that the company can target high-added-value markets. Nevertheless, the cost of working these materials can be higher (tools, new transformation processes).
- Innovation in these new materials is driven by the suppliers in response to a widespread demand for lighter products in a large number of sectors.

In technological terms

- Materials that can meet complex functional specifications for predetermined service lives, while withstanding severe operating conditions (corrosion, fatigue, strength, limiting of cold and hot cracking, high resistance to corrosion, biocompatibility, etc.).

FACT SHEET 1

VERY HIGH PERFORMANCE STEELS, NON-FERROUS ALLOYS AND SUPERALLOYS

In terms of business transformation

- Necessity to ramp up skills to master the working of new materials (tools, new transformation processes) and the design of parts (service life).

In environmental and societal terms

- Manufacturing steps that consume less energy with lower discharges into the atmosphere.
- Materials whose utilisation is driven by the trend for overall energy performance (lightening of structures signifying a reduction in fuel consumption and emissions in transport applications, for example).
- The tightening of environmental constraints increases the appeal of metals that resist corrosion without additional treatments.

▸ KEYS TO SUCCESS

In technological terms

- Avoid the risk of design errors when using new materials (the dissemination of data on the rules concerning the design and the working of these materials is still limited).
- Redesign at minimum cost.
- Assemble parts in different materials.
- Continue the drive to reduce the weight of structures and mechanical parts.
- Associate the use of these new materials with new working processes when necessary (e.g. hot pressing).
- Adapt these tooling materials according to the grades worked.

In digital terms

- Develop databases on these materials, their working and utilisation and their advantages and drawbacks with respect to alternative materials in order to capitalise internally on acquired knowledge.
- Use redesign-topology optimisation software tools.

In terms of skills to be mobilised, knowledge and training

- Develop skills in the working and the use of new materials.
- Initiate a watch to keep track of innovations and capitalise on the available data.

Questions to ask

- Does my customer's demand for weight reduction oblige the redesigning of parts and a change in the process of application?
- Are the fluctuations in raw material costs which affect the price of these new materials in phase with my business model?
- How can I capitalise on the first successful applications?

▸ MATURITY OF THE OFFER

Emerging	Laboratory	Proven	**Mature**	Frequent	Pervasive

▸ USEFUL LINKS

Author: Cabinet

Contributors: Cetim, Arts et Métiers (Laurent Barrallier MSMP)

FACT SHEET 4

INNOVATIVE ASSEMBLY

DESCRIPTION/DEFINITION

The products of the future will be made up of increasingly complex combinations of materials such that each one contributes its own specific advantage to the finished product (lightness, conductibility, strength, hardness, etc.). The growing diversity of materials (new metallic materials, composite materials, nanomaterials, biomaterials, etc.) is supplemented by increasingly varied combinations of materials. These new multi-material designs necessitate the implementation of innovative assembly techniques while still guaranteeing joints that ensure optimum properties of the resulting assembly.

Among the technologies used we can mention:

- techniques for assembling dissimilar metallic materials:
  - brazing, diffusion brazing;
  - solid-state welding processes such as diffusion welding, friction welding, friction stir welding (FSW), magnetic pulse welding (MPW).
- techniques for assembling a metallic material with a composite, plastic or dissimilar metallic material:
  - screwing, bolting;
  - nailing;
  - adhesive bonding
  - riveting-adhesive bonding;
  - welding-adhesive bonding;
  - clinching;
  - overmoulding;
  - processes such as Comeld™ and Surfi-Sculpt™.
- very-high-precision assembly techniques for MID (moulded interconnect device) parts or plastic or multi-material (metal/ceramic/polymer) micro parts.

ISSUES (BENEFITS)

In economic terms

- Alongside the potential additional costs associated with purchases of equipment intended for the new processes, multi-material assemblies make it possible to use costly materials only in strategic locations where they contribute high added value. The non-critical sections of a part can therefore be produced using cheaper materials.

In technological terms

- Multi-material assemblies allow the characteristics of each component material (lightness, conductibility, strength, hardness, etc.) to be turned to the best possible account. Multi-material parts are therefore optimised at several levels and can display better performance than single-material parts.

In environmental and societal terms

- By allowing the production of lighter parts while conserving their mechanical properties, innovative assemblies make it possible to reduce fuel consumption of vehicles and aircraft, and in the transport sector in general. Consequently, greenhouse gas and polluting emission are reduced.
- The use of new, "greener" adhesives (glues and structural adhesives which allow disassembly without using chemical products, for example) reduces the environmental impacts of adhesive bonding processes.

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INNOVATIVE ASSEMBLY

KEYS TO SUCCESS

In technological terms

Designs that use innovative assemblies and multi-materials necessitate:

- methodologies for dimensioning heterogeneous assemblies;
- means of qualifying the quality of the final assembly, preferably by non-destructive testing methods, and its durability according to in-service stresses:
  - > development of laboratory test methods for qualifying the strength of the assemblies;
  - > development of non-destructive test methods for in-process controls;
- control of problems of local embrittlement of structures (creep, peening, rupture of fibres);
- characterisation of the surface-preparation quality for adhesive bonding;
- acquisition of specific equipment for welding (controlled atmosphere or vacuum furnace, electromagnetic pulse welding machine);
- control of qualification of procedures (tightening torque on a composite material, difference in thermal expansion between a metal and a plastic, etc.).

In digital terms

- The use of multi-material products implies defining associated behaviour models and the corresponding databases, obtained by characterisation tests.

In terms of skills to be mobilised, knowledge and training

- The use of several materials in conjunction with one another can necessitate new skills, particularly in activities which are traditionally oriented exclusively towards the utilisation of metals and not of composite materials.

Questions to ask

- What are the consequences of innovative and multi-material assemblies on product lifecycle management (PLM)?
- Is there continuity in the digital tracking of the information concerning a part?

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

USEFUL LINKS

Contributor: Arts et Métiers (Laurent Langlois, LCFC)

FACT SHEET 6

AUTOMATION, COMPUTER-INTEGRATED MATERIAL HANDLING (TRANSITICS) AND PROCESS ROBOTICS

DESCRIPTION/DEFINITION

In a globalised industry where innovation times and short product lifecycles oblige maximum responsiveness and flexibility at all levels of the value chain, production facilities must increase their efforts to adapt to changes in manufacturing conditions.

Over and beyond workstation automation to cope with the increase in production rate, manufacturers and logisticians also seek to increase the flexibility of the production means, optimise the transfer of components from one station to another and maintain continuous procurement flows. This transformation in terms of process robotisation offers humans the possibility of concentrating on the tasks that require specific know-how and decision-making in order to optimise site management and control.

The main applications of these technologies are:

- handling loads, order preparation (order picking), sorting machines, overhead conveyors, elevators, storage and retrieval machine, palletisers and loaders, pick & place, case packing, palletisation;
- iron plating, laying sealing products;
- assembly, arc welding, applying adhesive, finishing;
- manufacture of printed circuit boards, treatment and packaging of electronic components, picking and placing electronic components on flexible substrates (textile, etc.) ;
- process operations in general.

ISSUES (BENEFITS)

In economic terms

- Reduction in cycle times and improved production rates, disappearance or reduction of bottlenecks.
- Flexibility.
- Improvement in the quality of processes and products.
- Meticulous capture of data.

In technological terms

The increase in the level of automation allows better organising of the work space, relieving personnel of arduous or laborious activities that create little added value, and facilitates the integration of on-line NDT systems. Robots can replace humans in hazardous environments.

In terms of business transformation

- Gaining in competitiveness in some cases eliminates the need to relocate or subcontract production, and can even permit the repatriation of subcontracted production.
- Process automation and robotisation mean that humans can devote more time to making decisions and analysing problems.
- New professional activities linked to the concept of cyber-physical systems are emerging, as automation and robotisation today are very closely linked to mobility.

FACT SHEET 6

AUTOMATION, COMPUTER-INTEGRATED MATERIAL HANDLING (TRANSITICS) AND PROCESS ROBOTICS

In environmental and societal terms

- Enhanced image of employees' work through an increase in their creation of added value.
- Improvement in the quality of operator workstations.
- Improvement in work conditions and safety; relief for operators on constraining, tiring or hazardous workstations which can affect their health (e.g. musculoskeletal disorders (MSD)).
- Allows time to be devoted to innovation and to focus on customer satisfaction.
- Enhancement of the company image, sensation of modernity and control.

KEYS TO SUCCESS

In technological terms

- With a view to optimising work by having robotic systems in the production line, it is necessary to analyse the movements, displacements and needs in terms of sensors.
- Mechanical, electrical, electronic and software integration in phase with the specific needs of the end-user.

In digital terms

- Increasing intelligence of systems: predictive maintenance, automated production control, data analysis, assisting operators in decision-making.
- Faster and more efficient image analysis and signal processing.

In terms of skills to be mobilised, knowledge and training

- Activities which are highly process-oriented to begin with will evolve towards greater control over the automated systems: project manager, production line or logistics controller, maintenance technician, robotics programmer, automation engineer, etc.
- The new skills will concern the integration of the processes and the organisation, modelling and simulation, supervision, safety and security, systems communication interfaces and protocols, immersion and e-maintenance.

Questions to ask

- What level of automation and robotisation is sought according to the budget and desired time frames?
- What tasks should be automated?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 13

SMART COMPONENTS

DESCRIPTION/DEFINITION

The production systems of the factory of the future will be based on components such as mechatronic actuators: in a given environment, the occurrence of a phenomenon – even unplanned – will give rise to decision-making by the components. The intelligence of these components is characterised by the following properties:

- intuitiveness when they are manipulated;
- an ability to communicate with the production process: the decisions are made and optimised on the basis of numerous items of information (control laws and models, sensors, mobilisable instantaneous power);
- a decentralised interconnection (Wi-Fi or industrial Ethernet, for example).

Smart components are therefore based on the Plug & Produce principle: the production stages are configured flexibly so that they can respond to changes of situation. The production network organisation is optimised by considering the overall value chain.

ISSUES (BENEFITS)

In economic terms

- The optimised hybrid use of several energy restitution solutions (oleopneumatic accumulators, flywheels, batteries, supercapacitors) and the integration of smart actuators in the items of equipment bring energy savings.
- The production flexibility made possible by smart components also implies higher production rates, therefore increased productivity.

In technological terms

- The integration of smart components makes it possible to increase the reliability of complex systems (self-diagnosis, self-adjustment, failure tolerance, redundancy through different technologies).
- Communication with other items of equipment allows the decentralisation of control functions, enabling shorter information processing times.

In terms of business transformation

- The intuitive and interactive human-machine interfaces enable better configuring of each smart component, thereby optimising their behaviour according to the specialist application.
- At the same time, the adaptability of smart components makes it possible to incorporate them in numerous items of equipment, which increases equipment flexibility.

In environmental and societal terms

- Process optimisation through the use of smart components also provides a possibility of improving accident prevention and process safety.

KEYS TO SUCCESS

In technological terms

The development of smart components necessitates :

- the creation of controls and compatible interfaces (for example, tractor/implement). The upgrades concerning their standardisation are to be observed attentively;
- the control of modelling and tests on hybrid operations;
- a gain in maturity with regard to the management of intermediate storages (oleopneumatic accumulators, flywheels, batteries, supercapacitors);
- development of control laws allowing the optimisation of movements and consumptions;

FACT SHEET 13

SMART COMPONENTS

- real-time adjustment of actuation to the targeted mechanical processes;
- miniaturised production of high-performance embedded systems.

In digital terms

- Communication is a core aspect of smart components. Some data are processed at component level (self-diagnosis, control law optimisation, degraded mode operation). The other data transmitted by the component must be optimised quantitatively and qualitatively, be reliable, and be interpretable by the component's environment.

In terms of skills to be mobilised, knowledge and training

- Promote training courses in mechatronics engineering.
- Reinforce the training courses for data science engineers.

Questions to ask

- What new services can be created using the functionalities offered by smart components?
- It is possible to effectively adapt production to each customer?
- To what level of product diversity are smart components capable of adapting?
- What is the response to the dilemma of mechatronic enhancement vs data production?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	**Frequent**	Pervasive

FACT SHEET 14

HIGH-VOLUME COMPOSITES

▸ DESCRIPTION/DEFINITION

The notion of producing high-volume composite parts is often associated with high production rates, that is to say of about one minute, for specific markets that integrate more and more composite materials in their products. It is important to note here that the high-volume composite approach fits into a rationale of technological disruption and assumes state-of-the-art know-how and a high level of industrialisation. Significant innovations are expected in this sector to improve performance, reduce production costs and cycles, and develop more environmentally friendly materials.

Main applications of these technologies:
The markets driving demand for composite material parts include aeronautics, the automotive sector for sports and electric vehicles, the building industry and wind turbines, as their blades get longer. The challenge is often to manufacture structural parts that are lighter than mechanical parts and stronger than plastic parts. The automotive industry is trying to integrate these materials into critical components (seat structure, dashboard reinforcement, chassis, spars). The aeronautics, civil engineering and recreational boat-building sectors are extending the application of composites to structural components.

Main technological segments concerned:

- long-fibre-reinforced thermoplastic (LFRT) matrix composites (prepregs, commingled yarns, etc.) and their application;
- fibre-reinforced thermoplastic matrix composites (carbon, glass fibres) and their application;
- filament winding;
- forming;
- incorporation of nanotechnologies (electrically conductive fillers, shock absorbing fillers, etc.) ;
- sequential injection;
- integration of functions (reinforcement, sound-proofing, fire-proofing, surface properties, self-repair);
- infusion forming, vacuum infusion;
- pultrusion forming;
- resin transfer moulding (RTM);
- long-fibre RTM;
- fibre placement – composites;
- reaction injection moulding (RIM);
- thermoforming;
- hybridisation of composite material implementation processes;
- high output and automated processes;
- hybrid composites - thermoplastic / thermosetting;
- smart composites

▸ ISSUES (BENEFITS)

In economic terms

- Reduction in manufacturing times and cost given the shapes that can be obtained and the possibility of integrating functions (instrumentation, etc.) to increase the utilisation rate in certain sectors.
- Robustness of market positioning.
- Optimistic growth and penetration rate prospects.
- Increased service life of parts and optimisation of certain properties (vibration, conductibility, corrosion, etc.).
- Reduction in material losses and rejects.
- Recyclability of thermoplastic composites.

FACT SHEET 14

HIGH-VOLUME COMPOSITES

In technological terms

- Reduction in product weight while still conserving high and orientable mechanical properties, corrosion resistance.
- Production of complex shapes (with made-to-measure materials) or large-sized shapes.
- Reduction of the number of parts, simplified assembly (including with metal parts).
- Integration of functions, shock absorption, vibration resistance, chemical inertness.
- Service life of part dependent on the process used.
- Reparability and recyclability of parts in certain cases.

In terms of business transformation

- Necessity to work with the entire supply chain, from researchers and equipment manufacturers through to the instructing parties to industrialise high-volume production.
- Possibility of changing business activity by switching from metallic to composite materials.

In environmental and societal terms

- The appropriate recycling channels have to be involved in the discussions (example: dissolving resins, extraction of fibres for reuse) to guarantee sustainable manufacturing.
- Composite material products are well accepted by the public.

▸ KEYS TO SUCCESS

An overall reflection on "material-process-tooling-product" is necessary to achieve the best performance, robustness, cycle and cost trade-off.

In technological terms

- Innovations associated with low-cost carbon fibres for applications produced in large series: to give an example, the use of lignin or other alternative precursors to reduce the price of carbon fibres is currently being studied.
- Development of glass fibres displaying enhanced mechanical and chemical performance.
- Develop "high production rate" processes:
  - > compression, injection and RTM are the most commonly used processes for large production series, whereas manual layup and vacuum RTM are reserved for production levels of less than 1000 parts per year;
  - > filament winding, spiralling and centrifuging are the methods of choice for cylindrical parts.
- Adaptation and/or development of continuous inspection technologies (shape, material soundness, etc.) appropriate for the parts and processes (high-resolution tomography, single and multi-element ultrasound transducers, active infrared thermography, X-ray radiography, terahertz (Thz) imaging).
- Adaptation of assembly processes, between one another and with metallic parts.
- Reduction in the composite material preparation time at the start of the process and in the manufacturing cycle time (robotisation, auto-adaptive control).

FACT SHEET 14

HIGH-VOLUME COMPOSITES

In digital terms

- The digital chain between processes and design must be as complete as possible.
- Design optimisation by using material databases.
- Make use of multi-material simulation/test technologies to:
  > optimise the reinforcement/matrix composition (reinforcement in the right place, in the right direction with the right meshing, while minimising material losses);
  > control the process viability associated with the anisotropy of composites.

In terms of skills to be mobilised, knowledge and training

- Necessity to get out of the "geometries and metalworking know-how" box; think "composite".
- Raise awareness on the integration of a maximum of functionalities when using the composite through hybridisation of the processes (insertion of components during manufacture).

Questions to ask

- Can I make this part in composite material?? What are the technical advantages?
- What functions can I integrate in the part?
- Is the ROI compatible with my investment strategy?

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

FACT SHEET 24

ADDITIVE MANUFACTURING

DESCRIPTION/DEFINITION

Additive manufacturing (or 3D printing) designates all the processes that allow physical objects to be manufactured directly from their digital model through layer-by-layer addition of material. There are many processes, differing in:

- the way in which the various layers of materials are deposited (fusion, sintering, polymerisation, etc.) ;
- the materials used in the form of solids (metallic powders, polymers, granules, etc.), liquids (photosensitive resin, etc.), or as semi-finished products (ribbons, wires, yarn, etc.).

These different processes, as opposed to conventional fabrication technologies (machining, forging, stamping), permit the fabrication of products of virtually any shape (customisable down to the single unit, adaptable to vast families of parts, etc.) which could not otherwise be produced (complex shapes, internal structures, lattices, etc.), with a minimal machine and tooling line.

Main applications of these technologies:
The current cost of production using these technologies makes them attractive at present on segments requiring complex parts produced in small/medium series. The most buoyant markets at present are aeronautics, space and the medical sector (high-added-value or customised metal parts). Usages are developing more generally in transport (automotive, rail, maritime), energy, consumer goods (luxury) and will ultimately spread to all industrial sectors (with specific associated needs and technologies). Four usages are often identified: part for rapid prototyping; tooling part (mould, gripper, adapter, etc.); intermediate part (which will be reworked); finished part (little reworking).

Main technological segments concerned:
There are many technologies of this type and they evolve rapidly with the progress of the machine manufacturers. They can be distinguished essentially through the materials used (metals, polymers/plastics, ceramics, cardboard, wood, concrete, etc.) and the source of energy or agglomeration used (laser or electron beam, arc melting, photopolymerisation, molten wire, sintering, lamination cutting, etc.). Various acronyms are used, sometimes associated with commercial offers which are often interchangeable, making the technological landscape more difficult to read. A typology can be consulted here[1].

ISSUES (BENEFITS)

In economic terms

- Simplicity of process implementation.
  - Reduction in the costs and production times for prototypes and small series of parts.
  - Optimised management of stocks (production on demand), spare parts and repairs.
  - Possibility of locating production close to the need (particularly for repairs and spare parts).
  - Versatility of the production means with respect to the parts produced.
- Optimisation of manufacturing processes
  - Reduction in the number of manufacturing steps required and the number of assembly operations.
  - Reduction in tooling quantities or optimisation of tooling (for example, creation of thermal cooling channels in moulds).
- Optimisation of the finished part
  - Addition of functions for equivalent manufacturing process, reduction in mass.
  - Creation of new geometries, new architectures, new materials.

1. https://www.3dhubs.com/s3fs-public/talk/attachments/Additive-Manufacturing-Infographic-3DHubs.png.

FACT SHEET 24

ADDITIVE MANUFACTURING

In technological terms

- Possibility of creating complex shapes (lattices, architectured materials) that are impossible to produce with conventional processes.
- Integration of functions: possibility of producing a part comprising several sub-systems in fewer stages, thus implying a reduction in the number of assembly operations.
- Opportunity to use new materials, venture into multi-material manufacturing.

In terms of business transformation

- Possibility of working with a network of suppliers and/or distributors to share the production means and optimise material costs.
- Reorganisation to bring the production units close to the sites of use or integration.
- Evolve towards customised product ranges and on-demand products, in a collaborative, short-loop service approach with the customer.
- Simplified utilisation of rapid prototyping to enhance the development of innovation processes and usages.

In environmental and societal terms

- Utilisation of material only where necessary: raw material savings with respect to subtractive processes.
- Optimisation of parts (weight reduction) and means of production (simplified, localised production line): reduction in energy consumption and carbon emissions.
- Transition from mass production to mass customisation.
- Possibility of including, as close as possible to the company, the user community's contributions to the processes of open innovation, new usages and production (similar to what can be found in the "Open-Source" software communities).

▸ KEYS TO SUCCESS

In technological terms

- Anticipate the production cost per part (linked to the machine production capacities):
  - > speed of printing;
  - > number of parts that can be printed simultaneously;
  - > size of the printable parts.
- Guarantee parts displaying good material quality thanks to better control of the manufacturing parameters (and the implications for critical parts that require certification or qualification, particularly in the transport and medical sectors).
- Integrate the quality control operations as close to the process as possible.
- Anticipate the finishing steps (with respect to the required surface conditions or state of the material).
- Consider the possibilities of joint utilisation of more conventional processes (forging, machining, stamping, etc.).

In digital terms

- Consider the new software integration capabilities between design, production (including post-processing) and quality control.
- Take into consideration the possibilities of simulation and capitalising on the data concerning the additive manufacturing process and material performance.
- Consider the new design opportunities that are suited to additive manufacturing (topological optimisation, etc.).
- Anticipate the implications with regard to counterfeiting, traceability and intellectual property associated with the digital models and the parts produced.

FACT SHEET 24

ADDITIVE MANUFACTURING

In terms of skills to be mobilised, knowledge and training

- Get away from the traditional manufacturing approach: design offices can now design with respect to a desired function rather than the manufacturing constraints of the processes.
- Rethink the design process for existing parts thanks to topological optimisation and the joint design of parts and their manufacturing machine parameters.
- Keep up to date with the rapid technological developments, usages and training offers (continuous and initial).

Questions to ask

- What are the impacts of additive manufacturing over and beyond the means of producing parts (flexibility of the production means, different way of managing stocks and logistics, new co-design or innovation relations with the customer-supplier, new business model, etc.)?
- What is the best approach between *make or buy* (should I buy a machine, use a subcontractor or share a machine, etc.) with respect to the maturity of the different processes and the health aspects of their implementation, particularly with respect to fine powder processes?
- What could be the impact on certification-qualification requirements in my sector?

► MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 25

RELIABILITY OF MECHATRONIC SYSTEMS

DESCRIPTION/DEFINITION

Reliability means the confidence, over time, that a user can place in an item of equipment or a system which is expected to render a service. It must be considered as a performance characteristic in its own right. Manufacturers must deploy the necessary means to attain the targeted reliability objectives. Mechatronic equipment items must function without failure for increasingly long periods of service. The particularly severe conditions of use of embedded mechatronics lead to the emergence of new failure mechanisms.

Main applications of these technologies:
Aerospace, agri-food business, automotive sector, chemicals/pharmaceuticals/cosmetics, defence, household appliances, energy, renewable energy, rail transport, paper industry, machine tools, packaging machines, additive manufacturing machines, textile machines, agricultural machinery, handling, public works equipment, medical equipment, robotics.

Main technological segments concerned:
Internet of Things, dependability, degraded modes, dynamic reliability models.

ISSUES (BENEFITS)

In economic terms

- Reduction in the number of critical components.
- Reduction in the cost and number of prototypes necessary for system validation.
- Reduction in the number of failures and therefore in equipment downtimes.
- Increased service life.

In technological terms

- Functional integration (collaboration between components in fulfilling the functions of the mechatronic system) and physical integration.
- Embedded information and connectivity with the networks.

In terms of business transformation

- Qualitative functional analyses (FAST - Functional Analysis System Technique, SADT -Structured Analysis and Design Technique, etc.) and dysfunctional analysis such FMECA (Failure Modes, Effects and Criticality Analysis) implying more experts and varied technical skills, dynamic reliability models (e.g. temperature variations).

In environmental and societal terms

- Reduction in energy consumption through better integration of the sub-systems.
- The emerging markets, which currently constitute the largest centres of growth, are becoming increasingly equipped.
- Enhanced user safety.
- Ergonomics: user information.

KEYS TO SUCCESS

In technological terms

- Understanding of the effects of thermal, vibrational, humidity, electrical and electromagnetic constraints, progressive integration of electronic components into embedded systems with severe environmental constraints.
- Predict the origin of a component failure.

In digital terms

- Management of control and regulation systems.
- Systems security and command access control.

FACT SHEET 25

RELIABILITY OF MECHATRONIC SYSTEMS

In terms of skills to be mobilised, knowledge and training

- Mechatronics necessitates the bringing together of varied technical skills (mechanics, hydraulics, pneumatics, electronics, computing, automatic control, metrology, etc.) which are pooled through co-engineering and collaborative work approaches.
- Mechatronics more specifically requires interchange between experts in different fields.

Questions to ask

- The combination of these technologies must be examined as from the mechatronic systems design phase in order to guarantee their reliability: functional analysis, simulation of dynamic behaviour and dependability assessment.

▸ MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 27

SURFACE FUNCTIONALISATION

DESCRIPTION/DEFINITION

The service properties of materials depend increasingly on their surface composition. Industry has effectively endeavoured, over the last thirty years in particular, to develop surface coatings and treatments that allow, by mechanical, physical, chemical or electrochemical means, the nature, composition, or structure of the surface of a material, or the state of its surface stresses to be modified, without changing or deteriorating its core characteristics. Surface treatments can therefore improve the surface properties of a material to give products greater added value by making them more resistant to corrosion, oxidation, wear or friction, or by improving their thermal or electrical performance or their weldability or simply their appearance, etc. It is thus possible, by protecting a carbon steel with a zinc coating, passivation and a paint system, to make it corrosion-resistant while at the same time maintaining excellent mechanical properties, as is the case with sheet metal for the automotive industry, for example.

The development of such treatments necessitated the setting up of analysis and monitoring tools in order to obtain reliable and reproducible parts.

Given the growth of the surface treatment industry, the analysis and more generally the characterisation of surfaces have today become a necessity in numerous areas: corrosion, oxidation, passivation, catalysis, wear, friction, lubrication, diffusion, adsorption, adherence, thermal and electrical conductivity, photovoltaics, etc. Depending on the problem studied and the properties involved, the definition of surface can vary greatly, from a strict single-layer or multi-layer coating (a few micrometres thick) to layers reaching several tens of micrometres or more, from 50 to 100 µm thickness of alumina (Al_2O_3) for example, after hard anodising treatment of an aluminium part.

A large variety of analysis methods exist, some of which are used essentially in university research centres or technical centres. A considerable increase in the number of machine locations is nonetheless observed further to the numerous developments, and today it depends firstly on the level of sophistication and progress of the technique and secondly on the added value of the analysed product. However, if we exclude microelectronics, few methods are suited to the inspection of industrial surfaces if the aim is to rapidly obtain information on a large number of elements and for extremely variable layer thicknesses, which is often the case after surface treatments or coatings. Furthermore, the quality of the samples does not always allow a high vacuum to be obtained (porosity, high surface roughness, presence of organic residues, etc.).

ISSUES (BENEFITS)

In economic terms

- Improve the surface properties of a material to give the products greater added value by making them more resistant to corrosion, oxidation, wear or friction, or by improving their thermal or electrical performance, their weldability or simply their appearance, etc.
- Expand the industrial offer with innovative and differentiating products.
- Possibility of "reconverting" products by giving them another function and thereby gaining access to new markets.
- Limiting wear, and therefore the amount of heat to dissipate, considerably reduces maintenance costs.

In technological terms

- The setting up of analysis and monitoring tools in order to obtain reliable and reproducible parts.

FACT SHEET 27

SURFACE FUNCTIONALISATION

- Attribute new functions to materials to meet a multitude of service objectives (friction, sealing, design aesthetics, electrical, optical, hydrophobic and oleophobic properties, anti-reflection, adherence, antibacterial, anti-counterfeit, anticorrosion, anti-icing, anti-graffiti, scratch resistance, fireproofing, cleanability, etc.).
- Possibility of combining functions.
- Increase the durability of surface integrity with respect to service stresses.
- Reduce the operating energy cost through controlled tribological characteristics.

KEYS TO SUCCESS

In technological terms

- Master the large variety of analysis methods available.
  - The choice of the technology that gives the desired characteristic implies specific reflection to find the right materials-characteristics-process-inspection trade-off, especially when looking for innovative properties.
  - The base material and added materials, if any, must be perfectly mastered. The statistical spread of the initial characteristics must not excessively disrupt the end result, or must at least allow the focus to be directed solely on the spread obtained by the functionalisation process.

In digital terms

The use of multiphysics simulation tools allows problems to be anticipated, tools to be optimised and parameters to be set. For example, heat treatment simulation gives the possibility of preventively describing the hardness profile, the concentration profiles, the level and direction of residual stresses and the level of strain. Simulation of growth of thin layers makes it possible to predict the surface structure and morphology of a deposit depending on the conditions of production applied, and therefore intrinsically its chemical composition and some of its mechanical and structural properties.

In terms of skills to be mobilised, knowledge and training

- Skills in adhesive bonding processes and their development, and in the inspection methods for these processes in terms of surface condition and surface functional properties.
- The skills to mobilise depend on the functionalisation process and the inspection methods. The majority of the processes nevertheless require sound knowledge of physics and chemistry and inspection and laboratory measuring techniques (micro/nano characterisation, etc.).

Questions to ask

- Do my parts display adequate mechanical and fatigue performance?
- Can I reconvert a product by giving it another function and thereby gain access to new markets?
- What surface functionalisation processes are economically and technologically accessible to me?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

USEFUL LINKS

Contributors: Arts et Métiers (Corinne Nouveau, LABOMAP)

FACT SHEET 28

INNOVATIVE OR OPTIMISED FORMING AND MACHINING

▸ DESCRIPTION/DEFINITION

This technological sheet designates new solutions brought to conventional forming and machining processes to gain in flexibility, quality and productivity.

Main applications of these technologies:
While the players directly concerned are situated mainly in the metal transformation sector (whether by the removal of material or the deformation of sheets), forming and machining technologies are ubiquitous and cut across many activity sectors: from energy, transport and the automotive sector to public works, electronics and the nuclear industry.

The main innovations to implement are described in the paragraph "Implications in technological terms".

▸ ISSUES (BENEFITS)

In economic terms

- Reduction in production costs (cycle type, handling time, reject rate).
- Increased agility to produce more part numbers in a given time and increase machine utilisation rate.
- Flexibility of the production means with a view to product customisation and reducing time to market.

In technological terms

For machining:
- process improvement by assistance with cutting to increase tool service life and obtain an improved surface condition using cryogenic, vibrational, ultrasound, high-pressure jet or laser technologies;
- add-on palletisation to provide greater flexibility and agility – for example, inspection on three-dimensional measuring machine during machining;
- utilisation of multi-process or hybrid machines to obtain finished parts directly without changing the reference datum;
- utilisation of auto-adaptive machines, that is to say which automatically adapt the machining parameters to the conditions prevailing during the operation (temperature, vibrations, power input, etc.).

For cutting-stamping:
- improvement in productivity and the formability of the sheet metal by using servo-presses (which allow previously unattainable travel speed profiles to be obtained);
- implementation of incremental forming technologies (kind of metal spinning extended to all shapes other than cylindrical) which allow small series to be produced without tools;
- implementation of high-speed forming and cutting technologies (adiabatic processes, electric discharge forming, magnetoforming) which permit extremely fast production rates and improve the quality of the manufactured parts;
- semi-hot (warm) forming applied to aluminiums – which until now could not be cold-formed – to reduce the weight of steel parts;
- press quenching to increase productivity (part treated in the tool).

In digital terms

- Instrumentation of tools to optimally adjust the manufacturing parameters and deliver parts that are 100% OK
- Digital simulation of processes taking into account the particularities of the professions increasingly well.
- Pallet instrumentation with embedded chips to obtain information in real time and put it directly into the MES (manufacturing execution system) so that scheduling is optimally matched to the needs.

FACT SHEET 28

INNOVATIVE OR OPTIMISED FORMING AND MACHINING

In environmental and societal terms

- Reduction in the quantity of harmful effluents generated by the machining or forming processes.
- Improvement in the biodegradability of biolubricants of vegetable origin.
- Working conditions improved by the reduction in effluents (cleaner and healthier environment).
- Reduction in rejects giving a cleaner and more competitive company.

In terms of business transformation

- Incremental innovation: relatively low impact on the production process or on the work or company organisation.

▸ KEYS TO SUCCESS

In technological terms

- Hot-forming processes are more difficult to master.
- Hybridisation of laser machining-forming and electromagnetic forming processes.
- Lubrication of light alloys (aluminium, magnesium) is more complex.
- Recent advances in sheet metal forming technologies which necessitate adaptation of the basic rules of the trade.

In digital terms

- The analysis of these processes by digital simulation requires in-depth knowledge of the plastic behaviour of the material.
- Development of tools for the modelling and digital simulation of electromagnetic forming processes.

In terms of skills to be mobilised, knowledge and training

- In the coming years, the machining sector will be impacted by ageing of workshop personnel, necessitating renewal of the workforce.
- Lack of knowledge of light alloy deformation laws for forming.
- Lack of knowledge of the behaviour of materials under the effect of electromagnetic forces.
- Conventional lubrication practices during machining and forming are firmly anchored.

Questions to ask

- How can I increase my productivity?
- How can I meet the change in my customer's quality demands?
- How can I reduce the number of operations required to manufacture my parts?
- How do I work the new materials imposed by my customers?
- How can I satisfy the increased production rates demanded by my customers?
- How can I cope with the reduction in the size of my production series?

▸ MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

FACT SHEET 38

SMART MACHINES

▸ DESCRIPTION/DEFINITION

Manufacturers who invest in smart factories, or "factories 4.0", predict gains in efficiency of 27% for manufacturing activities in the course of the next five years, that is to say a contribution of 500 billion dollars to the world economy in annual value added[1]. The smart factory, often considered to be the cornerstone of the digital industrial revolution, uses the latest technologies such as the IoT (Internet of Things), big data analysis, artificial intelligence and advanced robotics to gain in productivity, efficiency and flexibility. These state-of-the art factories use, for example, collaborative robots, augmented reality devices and machines that generate alerts automatically when they require maintenance.

According to a new Gartner report entitled "Smart Machines: Consulting and System Integration Services Market Forecast and Opportunities", almost one third of companies are going to use smart machines in one form or another over the next five years. By becoming commonplace, smart machines will open the era of a new industry, an industry which current estimates predict will be worth nearly 29 billion dollars in five years' time.

As time goes by, the increased opportunities created by the growing number of companies implementing more complex smart machines should be counterbalanced by a reduction in the costs of adoption, because each subsequent adoption of the same given smart machine solution will be cheaper and faster.

The development of industry 4.0 requires, among other things, modernisation of the equipment. Upgrading that enables productivity to be increased. While industry 4.0 is developing quite significantly in the various sectors of industry, the upgrading of infrastructures and production machines is a gradual process. Many companies are still using production means that need to be modernised. And in an industrial context increasingly marked by the merging of companies and the Internet, the needs are obviously proving to be substantial.

Automation is gaining ground thanks to the acceleration of development of machine learning solutions by the manufacturers. AI now gives machines the ability to learn on their own. This is particularly the case with multi-layer convolutional neural networks, inspired by the functioning of our own brains. A machine equipped with such a network has facial and voice recognition capabilities. Voice recognition can be used in automated language processing, for example.

We are now sharing the infosphere with artificial agents who are becoming increasingly intelligent, autonomous and even social. We must therefore get used to co-existing with digital entities that are increasingly numerous and perfected.

Digital technologies and computerisation started to replace labour in agriculture and industry decades ago. They are now hitting services. Nobody doubts that smart machines will increasingly represent an indispensable aid to humans in many sectors of activity.

▸ ISSUES (BENEFITS)

In economic terms

Thanks to gains in productivity and improved flexibility and efficiency, smart factories will be able to significantly reduce their operational costs:

- modernise their production machines in order to improve traceability in the production of their products;

1. https://www.capgemini.com/fr-fr/news/les-usines-intelligentes-contribueront-pour-500-milliards-de-dollars-a-leconomie-mondiale-au/

FACT SHEET 38

SMART MACHINES

- be able to use the information concerning the operators' manufacturing orders to integrate them directly in the production machines;
- collect data from the manufacturing processes;
- streamline logistics and hardware expenses and optimise equipment efficiency and production quality.

In technological terms

- Cognitive computing, artificial intelligence (AI), intelligent automation, automatic learning and deep learning are all considered to be "smart machines".
- Capability for continuous learning, faster than humans and from massive quantities of data, to create more value from them.

In terms of business transformation

The utilisation of these smart machines by companies can be a transforming change as much as it can be a disrupting change. These machines are going to profoundly change our way of working and producing value. The coming years will be crucial for manufacturers, because they will have to speed up their digital transformation and fine-tune their approaches to maximise commercial returns.

For service providers, smart machines represent opportunities to help companies to evaluate, select, implement, change and adapt their talents and their information technology and commercial processes.

Over the long term, smart machines will form an integral part of the content of the toolbox of service providers and will be integrated in all the new-generation service offers.

KEYS TO SUCCESS

In technological and digital terms

The integration and command of all the technologies included in the Industry 4.0 perimeter: IoT, big data, AI, blockchain, etc.

In terms of skills to be mobilised, knowledge and training

New activities should emerge, particularly in the areas of consulting, system integration, strategic design, training, deployment and integration. The advent of smart factories will transform the global labour market. The number of low-skilled jobs has already been reduced following the first waves of automation, and acquiring new skills has been become a vital necessity.

Highly skilled positions in areas such as automation, analysis and cybersecurity all represent job-creation opportunities.

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

FACT SHEET 39

INNOVATIVE OR OPTIMISED PROGRAMMABLE MACHINES

DESCRIPTION/DEFINITION

The digital transition, representing a change and competitiveness factor for companies, modernises production systems as a whole. It is a powerful lever for minimising costs and optimising industrial processes. This is because industrial competitiveness depends above all on the ability of companies to improve the performance of their production systems and to increase their flexibility and agility by mobilising numerous complementary technological bricks (calculation software and technologies, automation, cross-referencing information, networking) into which the materials and shaping processes are also integrated.

Mastering materials (metals, polymers, composites, etc.) and their working and implementation by transformation and assembly processes are key knowledge areas that consolidate industrial competitiveness. Materials today must satisfy increasingly stringent specifications: better performance, longer service lives, ever-lower life cycle costs, etc.

Designing advanced parts that have a high degree of complexity and entirely new properties and functions necessitates the use of multifunctional and multi-material manufacturing processes, like the multiprocess computer numerical control (CNC) machines and/or programmable-travel CNC machines, the aim of which is to reduce production cycle times or envisage operations that were previously impossible. These machines contribute greatly to the increased flexibility of the production means. These multifunction and multiprocess machines combine different approaches to manufacturing (additive manufacturing, machining, turning, grinding, texturing, etc.).

These processes sometimes represent the only possible way of producing parts with highly specific properties: complex shapes, lightened structures with hollow parts, multi-material assemblies, etc. Additive manufacturing techniques also enable savings in raw materials by producing parts to virtually the finished dimensions, thereby eliminating machining discards. Multi-material parts are likely to offer cost benefits, which explains why a constantly growing number of industries are using them.

ISSUES (BENEFITS)

In economic terms

- Considerable gains in performance in a whole range of industries, applications and machines.
- Development of an ability to adapt the machines to production needs and greater integration in the production system by integrating humans into these systems.

In technological terms

- Improved capabilities in terms of precision transformation of parts, reduction in times required for machine setting, process adjustment and integration in the automation systems.
- Rapid manufacturing measurements and adjustments.

In terms of business transformation

- Base discussions with suppliers on the most significant factors, question production feasibility, assess the manufacturing constraints and put them to the test, and use simulations to adapt, improve or customise the product.

In environmental and societal terms

The advanced manufacturing processes should ultimately allow parts with improved performance to be produced more cheaply. These processes thus represent a real opportunity for all branches of industry to improve performance, which means real benefits for the environment and society.

FACT SHEET 39

INNOVATIVE OR OPTIMISED PROGRAMMABLE MACHINES

KEYS TO SUCCESS

In technological and digital terms

- Robots and intelligent programmable logic controllers, capable of performing complex and precise tasks in a short lapse of time, and even to interact with their environment and use it to define autonomous actions.
- Comparison data recorded to define process corrections.
- Automation of tool corrector updating in the manufacturing processes.
- Machine learning for the registering of past actions and the self-improvement capability of processes to gain in efficiency and productivity.
- Capture, recognition, utilisation and advanced analysis of key data provided throughout the length of the production line.
- It is therefore absolutely essential that these big data technologies be appropriately regulated in terms of cybersecurity.

In terms of skills to be mobilised, knowledge and training

- Training courses must be provided to help master the new technologies and activities (the "talents of 4.0") in the same way as for big data programmers, simulation tools or robot managers, etc.

Questions to ask

- Evaluating the potential increase in performance resulting from the adoption of these new types of advanced industrial processes necessitates breaking down the barriers and constraints established in the conventional processes:
  - > if all current constraints on the production system were removed, what could be the resulting innovation capability of the production line and the associated economic gains?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 41

SMART MATERIALS AND ADAPTRONICS, FUNCTIONAL MATERIALS

▸ DESCRIPTION/DEFINITION

Materials with functional and evolving abilities which let them adapt in real time to the fluctuations of their environment (noise, vibration, structural deformation, etc.), and recover or generate energy. These various smart materials and active control systems are today destined to control noise, vibration or the deformation of structures or machines.

Main applications of these technologies: smart materials have the ability to interact with the external environment, which means they can behave like sensors, actuators, and sometimes like processors (to process, compare and store information). These intrinsic properties currently make them the subject of exploration for numerous applications: active control of structure or equipment to prevent the generation of noise or vibrations, heat recovery from motors, self-repairing structures (automotive, aeronautics, rail transport, energy, biomedical, and building and public works sectors).

Main technological segments concerned: integration of actuators/sensors using the intrinsic characteristics of materials for small movements; integration of sensors directly in materials to monitor structures (e.g. electroactive polymers in composites); vibrational isolation by active suspension (with magnetorheological fluids for example); multifunctional materials (a given material can be used as a sensor or an actuator); piezoelectric materials, magnetostrictive materials (deform under the action of a magnetic field or create a magnetic field under the effect of a deformation), antimicrobial materials, functionally graded materials, biomimetic structural materials, self-sealing materials, polymer materials transforming heat into energy, electrically charged polymers, supramolecular polymers, materials for extreme conditions, phase change materials; artificial skins making robots sensitive to touch; haptic systems.

▸ ISSUES (BENEFITS)

In economic terms

- Improved comfort for machine users: active control of noise (active window glazing to filter traffic noise) and vibrations (magnetorheological suspensions).
- Increased precision and speed of the production processes.

In technological terms

- Improved equipment responsiveness and flexibility due to the ability of smart materials to adapt to the facility operating conditions in real time: vibrational isolation by active suspensions, active structural control to attenuate noise or prevent the generation of noise.
- Enhanced performance of actuators or sensors which use the physical properties of the material (physical, chemical or mechanical). Profound transformation in the design of future electromechanical systems, whereby it will be possible to integrate electronic devices (sensors, printed circuits, chips) in the material during the additive manufacturing process.

In terms of business transformation

- Profound transformation of practices at all levels of the value chain: research and development, production, maintenance and marketing.

In environmental and societal terms

- Optimisation of equipment energy consumption according to conditions.
- Increased user safety through structural monitoring.
- Reduction in noise pollution.

FACT SHEET 41

SMART MATERIALS AND ADAPTRONICS, FUNCTIONAL MATERIALS

KEYS TO SUCCESS

In technological terms

- In structural monitoring, difficulties in differentiating a failure from a structural discontinuity (hole, reinforcement, etc.) and in exploiting the signals when the machines are operating (vibration disturbance for example).
- Techniques for integrating sensors and actuators in the materials are still insufficiently mastered.
- High costs of components and finished products.
- Development of new non-destructive testing solutions corresponding to the particularities of the defects and ageing/rupture phenomena affecting smart materials.

In digital terms

- Reinforcement of the digital chain between materials development, product design, functional optimisation, the manufacturing processes, maintenance, etc.
- Design optimisation by using material databases
- Additive manufacturing: topological optimisation to produce functionally and performance graded components.
- Digital control of component insertion and deposition of printed circuit layers on or in the parts. Mechanical parts become connected electromechanical systems.

In terms of skills to be mobilised, knowledge and training

- The deployment of adaptronics implies combining skills in materials, regulation, electronics, computation, systems integration, manufacturing techniques and reliability.
- Personnel must be made aware of the possibilities of integrating functions and functionalities in new products.

Questions to ask

- Widespread application of active control of vibration and noise in many areas to enhance user comfort and increase equipment service life.
- Deployment and penetration rate of 4D printing (manufacture of objects capable of transforming themselves over time (self-assembly, movement, retraction, etc.) in response to external stimulations, a technology that represents a horizon for the industrialisation of manufacturing processes.
- Development of robot "sensitivity" by using artificial skins.

MATURITY OF THE OFFER

Emerging	**Laboratory**	Proven	Mature	Frequent	Pervasive

FACT SHEET 42

NON-METALLIC AND BIOSOURCED MATERIALS

DESCRIPTION/DEFINITION

Biosourced products for chemicals and materials are industrial non-food products obtained from renewable raw materials obtained from biomass (vegetable matter for example). In a context where the depletion of fossil resources (oil, ores, etc.) and the increase in the prices of materials on account of this phenomenon is a reality, it appears necessary to seek new biomass-based solutions. Furthermore, the impact of current practices on the environment is pushing this dynamic trend towards greener energies and solutions, in particular with biosourced materials and substances. Biosourced materials, whatever the sector of use, are materials that satisfy the required technical criteria (in the construction or green chemicals sector, for example), but also environmental criteria, throughout their life cycle.

Nevertheless, the draft laws and objectives resulting from the Grenelle Environment Forum of 2007 in Paris and more recently the French "Energy transition for green growth" law (Law No. 2015-992 of 17 August 2015) could help get this approach off the ground. Research laboratories and technical centres are developing technical validation processes for activity sectors for mid-sized, small, medium, and very small enterprises. The players backed by the laboratories and research centres focusing on innovative materials, processes and products, (example: the CSTB – French Scientific and Technical Council for the Building Industry) and which are supported by measures controlled by the ADEME (French Environmental and Energy Management Agency) are able to develop and propose alternative solutions based on biosourced materials. Thus, the number of application markets and instructing parties launching ranges of biosourced products is rising constantly.

Main applications of these technologies: automotive, aeronautics, rail transport, energy, oil and gas, biomedical and health, textiles, agri-food business, construction, capital goods sectors, etc. More generally, this concerns all sectors in which materials play a significant functional role by their mass or their surface area.

Main technological segments concerned: biofluids, agri-solvents (derivatives of terpenes, vegetable-oil methyl esters, alcohols, etc.), agri-lubricants, biomaterials (biosourced rubber, etc.), fibres of plant origin (linen, hemp, miscanthus, wood, kenaf, etc.) for use as reinforcements in composite material parts, bionanocomposites (derivatives of starch and cellulose, of polylactic acid, of polycaprolactone, of PBS and PHB), formulation of matrices for high-performance polyamide-based thermoplastic composites, thermosetting composites, biosourced fats, nanoparticles (cellulose microfibrils, nanocellulose), filled and nanofilled elastomers, fluorinated elastomers, silicones, bio/wood thermoplastic composites, biosourced additives, plant-origin fillers, partially biosourced polymers (PU foams, castor oil-based polyamides, bio-PET and bio-PE, PP, etc.), surface treatment.

ISSUES (BENEFITS)

In economic terms

- Reduce the impact of the cost of oil (fuel) and CO_2 emissions.
- Diversify the raw material supply sources.
- Benefit from a return on investment that is attractive over the long term (taking into account design, manufacture, maintenance and the problems avoided, such as pollution and deconstruction).

In technological terms

- Technical qualities and performance that are sustained over time.
- New properties of the biomass-based materials and products.

FACT SHEET 42

NON-METALLIC AND BIOSOURCED MATERIALS

- Material recycling is facilitated and the environmental and health benefits are greater.
- New processes for the production of carbon fibres from renewable low-cost precursors: lignocellulosic biomass and carbon nanotubes.

In environmental and societal terms

- Low environmental impacts.
- Reduction in the ecological footprint of the construction.
- Reduction in the toxicological and ecotoxicological risks.
- Creation of jobs in France, where the development of biosourced materials has been much slower than in Northern Europe, Germany and the Netherlands.

KEYS TO SUCCESS

In technological terms

- Identification of sources of alternative materials and substances.
- Management/utilisation of natural raw material resources.
- Make a better assessment of the true environmental impact of these materials (method of calculation).
- R&D to be carried out to test the new products (ex: corrosion resistance in contact with biofluids, stability of polylactic acid) and associated processes.
- R&D to be carried out to develop new transformations of biomass or repurposing of co-products.
- Degree of maturity varies according to the materials.
- Mastering new materials (technical complexity, performance, etc.), their properties and the implementation (lack of perspective on the ageing of parts).
- Overcome the deficiencies in the image and visibility of the "biosourced" sector.
- Recyclability, standardisation and labels (e.g. bio-matter content, renewable nature, environmental performance, etc.).

In digital terms

- New techniques for digital modelling of the biosourced material transformation processes must achieve a higher level of maturity.
- Examples of digital simulation research into heat and moisture transfers in a multilayer building wall made from biosourced materials.
- The "Fibres-Energivie" competitiveness cluster is embarking on professional training in biosourced materials and digital mock-ups for the building sectors.
- Creation and dissemination of "market place" information about the suppliers, availabilities and properties of biosourced materials or components.

In terms of skills to be mobilised, knowledge and training

- In partnership with trade organisations and green building associations, the regions are fostering the ramping up of skills of thousands of professionals in the areas of renewable energies and energy efficiency.
- Involvement with players in the upstream sectors (from seeds to the tree or the plant) stemming from the agro-industry sectors.

Questions to ask

- Does the lack of maturity of the technologies associated with biosourced materials not cause companies to hold back on raising skills levels?
- Standardisation of biosourced raw materials.

FACT SHEET 42

NON-METALLIC AND BIOSOURCED MATERIALS

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

USEFUL LINKS

Contributors: Arts et Métiers (Nicolas Perry I2M)

FACT SHEET 44

MICROFABRICATION

▸ DESCRIPTION/DEFINITION

In a world where there is a constant drive for ever-smaller components, microfabrication and the associated techniques are developing enormously. It is characterised by the fabrication of parts of millimetric to micrometric size stemming from techniques developed for watchmaking, the jewellery trade, mechanics and electronics. Microfabrication has paved the way for nanofabrication, which is now used extensively in the semi-conductor industry.

Main applications of these technologies: microfabrication represents a technical and scientific challenge in many areas: consumer electronics, aeronautics (onboard measuring electronics, cabin pressure, etc.), automotive, medical (eye surgery, ultrasonography, lab-on-chip, implants, medical devices), industrial processes. Watchmaking, jewellery, mechanics and electronics are traditionally the major consumers of these technologies.

Main technological segments concerned: *desktop factory* (micro-factory the size of an office), micro-assembly, micro-turning, multifunction microfabrication, sheet metal microforming, micrologistics and microtransitics, micro-injection moulding, micro-multi-material moulding, micro-punching, micro-bending and micro-stamping, micro-laser welding, micromachining, chemical micromachining, nano- and micro-extrusion of plastic films, micro-thermoforming, verification of thicknesses of nanometric multilayer films, verification of micro- and nano-electrical discharge machining processes and plastic parts.

ISSUES (BENEFITS)

In economic terms

- Microfabrication meets the needs of miniaturisation, compactness and weight reduction expressed in many contracts in order, for example, to add sensors or actuators, increase the intelligence of these components, or reduce overall dimensions, and so on.
- Microfabrication allows production rates to be increased thanks in particular to the techniques of forming foils and very thin sheets or strips on metallic parts.
- The low cost of a micromachine is an important factor, as is its small size, if the factory is situated in an area where land is expensive.

In technological terms

- For a given equivalent function, microsystems provide savings in volume and weight. Conversely, they allow more functions to be fulfilled in a same given volume.
- Low masses involved and development of new modes of actuation (electrostatic for example).
- Offer new products which cannot be produced with conventional techniques.
- Increase robustness with respect to equivalent macroscopic parts due to their small size and the use of materials that are proportionally much more robust (because they are monocrystalline, for example).

In terms of business transformation

- Some machining specialists are turning towards microfabrication.
- In order to envisage a replacement for the factory in the town, it must be environmentally friendly, consume little energy and be easy to reconfigure.

FACT SHEET 44

MICROFABRICATION

- China should become one of the main markets specialised in micro-technologies in the next few years.
- Greater flexibility on the production equipment.

In environmental and societal terms

- Microfabrication reduces material and energy consumption. Microfabrication effectively results in savings in the raw materials used in the fabrication of certain parts.
- Reduction in energy consumption insofar as the consumption of microsystems is often less than that of the equivalent system.

► KEYS TO SUCCESS

In technological terms

- Mastery of new tools opening the road to diverse sectors: micro-cutting tools, grasping micromechanical parts, 5-axis micromachining, micro-welding and laser micromachining, assembly, mounting, micro-turning, micro-injection moulding, nano-electrical discharge machining, multifunction microfabrication machines, sheet metal microforming: micro-punching, micro-bending and micro-stamping.
- Increasing use of the laser as a microfabrication tool (cutting, welding, machining, marking, texturing).

In digital terms

- Adaptation of computer-aided manufacturing (CAM) software and development of NDT solutions compatible with the dimensions.
- Development of 3D visualisation solutions for the microfabrication of MEMS (microelectromechanical systems).
- Improvement in the performance of feedback control systems in micromachining machines.

In terms of skills to be mobilised, knowledge and training

- Specific tooling and qualified labour for the operations.
- Familiarise operators with specialising the machines for a small number of operations rather than having cumbersome machines capable of doing everything.
- Master the physical phenomena on the micro or nanometric scale.
- Sound knowledge of the numerous microfabrication techniques.

Questions to ask

- Role of additive manufacturing in the manufacture of micro-components.
- The somewhat "gadget-like" appearance of desktop factory machines can deter some users.
- Even though the micro-scale technologies are known, the industrial and health risks that could result from nanotechnologies are yet to be properly evaluated.
- Adapting to the change of scale (in particular the problem of picking up parts or the impact on the quality of the part).

► MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	**Frequent**	Pervasive

FACT SHEET 50

NEAR NET SHAPE PROCESSES

▸ DESCRIPTION/DEFINITION

Processes that produce increasingly complex metal or plastic parts which are very close to their final (net) shape, thereby greatly reducing the finishing operations, which usually involve machining. The use of these processes enables a reduction in production times, cost, and material losses, as well as opening up new possibilities in the shapes of parts.

Near Net Shape (NNS) components are parts produced to virtually their final shape and which require just one finishing step to meet the required specifications, such as precise dimensions or a given degree of surface roughness.

Main applications of these technologies: although the players directly concerned are chiefly in the metal transformation sector, the near-net-shape technologies and manufacturing processes are used in numerous sectors of activity: automotive, aeronautics, energy, oil & gas, biomedical-health, capital goods, luxury goods.

Main technological segments concerned: hot isostatic pressing (HIP), spark plasma sintering (SPS), microwave sintering, powder injection moulding (PIM), integrated casting and forging process (ICFP), thixoforming, thixomoulding, thixoforging.

▸ ISSUES (BENEFITS)

In economic terms

- Net-shape production of complex high-performance parts made from materials that are difficult to machine (example: powder injection moulding – PIM).
- Reduction in costs associated with stocks and raw material wastage.
- Speeding up of development and prototyping cycles, carried out in a single operation (e.g. thixoforming) instead of several operations with conventional processes.

In technological terms

- Possibility of shaping materials and alloys that are difficult to machine or forge, etc.
- Elimination of the porosities in metal components (castings, metal injection moulding (MIM), additive manufacturing by laser or electron beam) and finishing operations.
- Fabrication of complex-shaped parts from powder metallurgy (selective laser sintering (SLS), HIP).
- Improvement in mechanical properties (fatigue, elongation, hardness).
- Reduction in heat treatments (spark plasma sintering, microwave sintering).

In terms of business transformation

- The advances in additive manufacturing (selective sintering, melting) and particularly in terms of surface finish quality, make it possible in certain niche applications to envisage relocating production to be near the utilisation sites (repair centre, on-demand manufacture of spare parts).

In environmental and societal terms

- In the current global context, the trend is turning towards technological processes with low energy consumption.
- Powder processes enable substantial savings in raw materials compared with machining (which produces large amounts of waste).
- Semi-solid forming techniques produce parts that are very close to their final shape and require less energy than conventional hot forging.

FACT SHEET 50

NEAR NET SHAPE PROCESSES

KEYS TO SUCCESS

In technological terms

- These processes necessitate in-depth knowledge of the materials and often post-processing expertise.
- They necessitate a fine-adjustment phase to gain full control of production stability and quality.

In digital terms

- Iterative simulation of the manufacturing process until the optimum experimentally validated process is obtained.
- Modelling of processes that are little-developed and little-known to users.
- New algorithms will be able to be used equally well for the finishing process as for the production of 3D models.

In terms of skills to be mobilised, knowledge and training

- The flexibility of the manufacturing processes requires professions and skills to evolve to take into account the hybridisation of technologies: computing, automation, profession associated with the process implemented, inspection techniques, etc.

Questions to ask

- What is the return on investment with respect to the cost of near-net-shape manufacturing machines such as debinding and sintering machines?
- The technology readiness level (TRL) varies according to the process (average of 7), but magnesium thixomoulding, HIP and MIM have a TRL of 9.
- What is the best trade-off between the mechanical characteristics and high corrosion resistance?

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

FACT SHEET 51

CLEAN PROCESSES

▸ DESCRIPTION/DEFINITION

In the production industry, and more particularly in the chemical industry, there is an urgent need for processes that are more acceptable with regard to the conservation of the environment. This trend towards what are now referred to as "clean processes" requires the traditional concepts of process efficiency to evolve towards an evaluation that integrates the economic value of eliminating waste at source.

The term "clean technology" covers any manufacturing method or process that uses the raw materials and/or energy as rationally as possible while at the same time reducing the quantity of polluting effluents, waste, or product discards during manufacture or utilisation of the product.

Clean and low-carbon technologies provide a means of reconciling industrial production with protection of the environment, and all the more effectively given that their adoption also results in economic and strategic advantages for the company. These technologies take into account the restrictions or bans on the use of materials and substances referenced in the regulations (REACH for example) or in the process of being banned.

Three distinct but complementary objectives spur the introduction of clean processes:

- the reduction in raw material consumption;
- the reduction in energy consumption;
- the minimising of waste and effluent production.

It is therefore a question of combining ecological and economic interests by saving on the use of raw materials and energy consumption and by improving the performance and quality of the finished product.

Thus, with little or no waste produced, the benefits are materialised as gains in production as well as savings on the payment of pollution taxes. Clean technologies are defined by a series of steps, applied according to the nature of the identified problems and the complexity of the work required, to integrate operations into an industrial process.

Three complementary methods coexist:

- optimisation of the existing process;
- substitution of current technologies by others that are less polluting;
- and/or modification of the process.

Defined in an IPPC (*Integrated Pollution Prevention and Control*) directive, the best available techniques (BAT) aim at minimising all the harmful effects of the majority of industrial activities within the European Union (emissions of potential pollutants into the atmosphere, water and ground; noise, odours, accidents, etc.). Industrial facility operators thus find themselves obliged to prevent environmental pollution using the BATs as a yardstick. The indicators are not limited to emissions alone; they include the minimising and recycling of waste, energy efficiency and the prevention of accidents affecting the environment (reduction in the consequences of accidents and rehabilitation of sites).

To conclude, the BATs can be summarised by:

- best: the most efficient technologies for achieving a high overall level of environmental protection;
- available: under economically and technically viable conditions;
- techniques: the technologies used, the way in which the facility is designed, built, operated and decommissioned. The BATs are not necessarily all applicable to each facility as a matter of course.

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CLEAN PROCESSES

The EU has developed a certification for innovating companies that are particularly involved in clean approaches. It also gives a guarantee on the environmental friendliness of the processes used and on the company's ability to conduct self-assessment and improve itself.

For example, white biotechnologies could be a good alternative to certain conventional chemical processes from both an economic and an environmental point of view. They consist in using biological systems such as micro-organisms or enzymes to develop fermentation or catalytic processes to produce chemical intermediates and bioenergy from biomass. Thanks to the unprecedented progress in biology since the end of the 20th century, particularly in knowledge of the living world, genetic engineering is today more than ever armed to do what nature would take several thousands of years to do.

Although biomass offers many advantages, it must be exploited without sacrificing the food sector in the process. The future lies more in the second generation of biofuels, which would use the entire plant (straw, stems, trunk) and extract from it the lignocellulose, a molecule contained in all plant cells (especially the wood of fast-growing trees and straw); it would then be possible to exploit the non-foodstuff biomass, or even its waste, the combustion of which would moreover provide energy for its extraction with low greenhouse gas emissions.

Given current global dynamics, we can reasonably believe that plant chemistry is promised a major place in industry and among our standard consumer goods. These approaches nevertheless apply to all production process, all sectors considered, to the primary or secondary production stages as well as to the end-of-life stages of the products and goods.

► ISSUES (BENEFITS)

In economic terms

The competitiveness of the company: the quest to reduce consumption and make savings is associated with heightened performance and even innovations. The company will also be more attractive for its employees and its customers.

The long-term continuity of the activity: over and beyond regulatory compliance, lasting and appropriate solutions push back the risk of obsolescence and of banning or rejection by stakeholders. The lower dependence on resources (energy, water, raw materials) is also an advantage.

- Integration of the notion of cleanliness and sobriety in the development of products leading to greater reliability and reduced operating costs.
- With regard to the processes: putting in place techniques and/or good practices aiming to eliminate waste or to treat it at source, reduce consumptions, recycle water, thereby reducing costs through better management of the production means (use of the Best Available Techniques described in the BREF documents associated with the Industrial Emissions Directive (IED).

In technological terms

- Development of systems (sensors and information processing) analysing in real time the consumptions and discharges of a product, equipment item or process with management of alerts and exploitation of the gains/savings.
- Widespread adoption of green information technology (reduction in water and energy consumption, recycling of water, optimised computational algorithms, etc.).

In terms of business transformation

A company that continuously improves the cleanness of its production means, with a sustainable outlook and putting in place effective project management methods (Kaisen, 5S,

FACT SHEET 51

CLEAN PROCESSES

etc.) will see a significant reduction in its land use. The saved surface area can be used to increase its activity or start new ones.

In environmental and societal terms

A clean factory becomes compatible with the modern town again, which can bring the workplace closer to where people live and therefore reduce the carbon footprint associated with travel.
A clean factory also leads to a work environment compatible with safer and less toxic conditions for the employees.

▸ KEYS TO SUCCESS

In technological terms

Clean technologies can be integrated into a company at three separate levels with a view to limiting the production of waste, discards, etc. at source :

- the implementation of good practices that put in place organisational measures (e.g. monitoring and maintenance of cutting fluids to increase their service life and thereby reduce the volume consumed and the waste bill);
- the integration of additional treatment means (e.g. installation of an evaporator/concentrator to reduce the volume of aqueous effluents treated and recycle the water collected);
- the replacement of technologies (e.g.: replacement of grinding operations, which create machining sludge and effluents, by hard turning or powder metallurgy shaping processes);
- the integration of sensors (coupled with finer process simulations), throughout the process to better control and manage the production systems.

Questions to ask

- Where do the losses through wastage occur? How can the comfort margin be differentiated from the safety margin in the instructions? How can equipment saturation be improved? What good scheduling practices should be adopted? How do you size the thermal and airflow utilities?
- In what way can clean technologies help to improve my competitiveness? Are my customers sensitive to the company image or do they demand environmental performance? Is the environmental performance of my processes a requirement for them to be acceptable to the local authorities or for the long-term continuity of my activity? Can the reduced environmental impact of my products contribute to my development strategy?
- What are the appropriate orders of size and scales of measurement to be entered into the dashboards or technical, economic and environmental control models? Can processes which aim at reducing emissions and minimising consumptions be anticipated and scheduled?

▸ MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

▸ USEFUL LINKS

Contributors: Arts et Métiers (Nicolas Perry I2M)

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REMOTE MONITORING

DESCRIPTION/DEFINITION

Remote monitoring in industry takes advantage of the progress made in the areas of telecommunications, sensors, the Internet of Things, or in the processing of acoustic, vibrational, thermal or electric signals. This notion encompasses a set of technologies that can be used to remotely monitor a means of production, either by an Internet telephone link or by mobile means such as smartphones or tablets. They allow, for example, a maintenance operator to be remotely assisted in a repair task by a specialist who has the required information in real time.

This monitoring function provides the possibility of detecting continuously and in real time any damage to, or drifts in, the production systems, which means that a predictive maintenance system can be put in place. Communicating sensors, for example, are starting to be integrated in components at manufacture (bearings). This represents the first step towards integrating a monitoring function and evolving towards on-condition maintenance depending on the state of the machine.

Main applications of these technologies:
Automotive, aeronautics, rail transport, energy, mines and quarries, oil and gas, biomedical-health, agri-food industry, agricultural machinery, public works equipment, special machines, machine tools, paper industry, chemical-pharmaceuticals-cosmetology, building industry for recording parameters, monitoring fleets, predictive analysis or non-destructive testing.

Main technological segments concerned:
Automation of monitoring and interventions; remote consulting; access to remotely located experts; artificial intelligence; learning systems; equipment modelling; signal processing; choice of indicator variables; centralised means for expert assessment, data, and access to the remote machines; resource sharing.

ISSUES (BENEFITS)

In economic terms

- To be competitive and stand out from the competition, European manufacturers seek to improve their after-sales service and to develop complementary services for their customers.
- Increased productivity and availability of the means.
- Minimisation of repair times and costs thanks to failure prediction.
- Increased equipment service life.
- Optimisation of the movements of *in situ* experts.

In technological terms

- Early detection of failures, predictive and staggered maintenance operations.
- Knowledge, potentially in real time, of stresses affecting the materials.
- The means of communication, big data and the pools of experts promote rapid remote diagnosis and assistance.
- Aid in the prediction of accident risks.

In terms of business transformation

- Minimisation of maintenance, speed of maintenance intervention on machine, transparency, events traceability.
- Possibility of remotely consulting the equipment items and having them analysed by remotely located experts who are not on site.
- Anticipation of spare parts requirements to reduce supply disruptions and optimise the logistics chain.

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REMOTE MONITORING

In environmental and societal terms

- Know the stresses at all times, prevent catastrophic failures (aircraft, ships, oil and gas) in order to reinforce the safety of users and personnel.
- Better monitoring of the energy efficiency of the machines and decision-making support tool to reduce energy consumption.

KEYS TO SUCCESS

In technological terms

- Check the relevance of the choice of variables transmitted by the sensors before they are put into service.
- The progress made in the areas of equipment and process modelling, prediction, artificial intelligence, smart data, big data, data merging, health monitoring,, remaining service life calculation and learning systems concerns high-value equipment items first and foremost.

In digital terms

- Guarantee the confidentiality of the exchanged data.
- The vast dissemination of digital technology enables benefit to be drawn from the Internet of Things and from the cloud. The exchange protocols and standards of the professions are updated in accordance with these developments.
- The maintenance companies have improved means: more portable devices, downsizing, applications on mobile devices and drones.
- Cross-check data from several sources.

In terms of skills to be mobilised, knowledge and training

- Develop aids for failure diagnosis, decision making (shutdown, degraded mode, repair, etc.) and equipment management.
- Develop centralised means for expert assessment, data management, access to remote machines, resource sharing, decision-making support.

Questions to ask

- What influence does the contractual aspect (insurance, liabilities, results commitments) have on remote monitoring? What are the cybersecurity risks?
- Calculation of return on investment from implementing remote monitoring?
- "Heterogeneous" monitoring, that is to say monitoring a mix of modern and older-generation machines, and retrofitting old-generation machines with connected solutions, remains a necessity.
- Transformation of economic models and development of new offers: for example, some equipment manufacturers propose maintenance contracts that include monitoring of the equipment pool and specialised services, as is the case with the bearing manufacturer SKF, with its *Rotation For Life* offer (supply of bearings, lubrication management, remote diagnosis and analysis of causes of failure), defined to meet performance targets agreed with the customer.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	**Mature**	Frequent	Pervasive

FACT SHEET 58

DIGITAL COMMAND-CONTROL SYSTEMS

DESCRIPTION/DEFINITION

Automation, a discipline dedicated to the command and control of feedback control systems, has benefited to the full from the growth of industrial information technology. Thanks to this, industrial machines are less and less dependent on humans, making it possible to increase efficiency and repeatability. Even if certain processes impose a significant constraint on the functioning of these systems: the time factor.

Industrial automation systems designed to be compatible with the Industrial Internet of Things and Industry 4.0 concepts must cover different command-control levels, each with their own design challenges to be taken up, and which require optimised hardware and software solutions.

A distributed control system (DCS) is an industrial control system intended for factories or industrial processes whose control components are distributed or geo-distributed. Unlike centralised control systems which have a single central controller managing all the system's command-control functions, DCSs are made up of several controllers which control the sub-systems or units of the installation as a whole.
Distributed control systems are used primarily in industries involving processes integrating management by batch or by recipe. DCSs can be found, for example, in the oil and refining industries, in energy production stations, in cement works, in the pharmaceutical industry, etc.

Key concepts such as intelligent maintenance, based on predictive analysis, and decentralised intelligent actuators, are already resulting in many advantages, such as greater flexibility, increased efficiency and shorter shutdown times for maintenance work. Their implementation nevertheless accentuates the design challenges for automation equipment on production sites.

Industrial automation systems designed to allow implementation of the Industry 4.0 concept essentially comprise three levels of equipment which manage the communications and command-control operations in real time:

- the ground level with the input/output modules, the actuators which ensure the physical operation of the industrial equipment on the site, and the intelligent actuators which in addition receive information from their environment, communicate with one another and thereby contribute to the decentralisation of the command-control functions;
- the command-control level with the PLCs (programmable logic controllers) and CNC (computer numerical control) machines, which collect the information from the ground level in order to control the process functions which remain centralised (example: on/off modes, control of safety functions);
- the operator level with the human-machine interfaces (operator consoles) which communicate information to the operators for command-control purposes.

For each of these levels, the conventional silo-based design rules have to be reconsidered in order to optimise the hardware and software solutions which manage the communications and command-control functions. It is important to understand the relevance of decentralising the command-control functions to the intelligent actuators. The intelligent actuators are self-controlling, but they also process information from their environment in order to act on it to optimise production efficiency. They thus help make the communication networks (information, command signals) less dispersed, help reduce data analysis times by reducing their transit distances, and help industrial automation systems consume less energy.

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DIGITAL COMMAND-CONTROL SYSTEMS

ISSUES (BENEFITS)

In economic terms

- Improve competitiveness and performance.
- Provide real-time diagnosis solutions.

In technological terms

- Actuators capable of estimating their remaining useful life (RUL).
- Actuators which command and control other actuators.
- Actuators which process data from external sources. Cloud connectivity necessary for the transmission of data used by the predictive analysis function.
- Real-time operating systems (RTOS) and peripheral devices for industrial communications, characterised by their ability to respond to time-related constraints.
- Industrial fieldbus protocols supported, ensuring low latency and reduced cycle times.
- Multi-protocol supported to ensure compatibility between the different standards.
- Have a large number of peripheral interfaces, Ethernet in particular, and a programmable and flexible communication solution to give developers the possibility of creating more efficient automation solutions, adapting to fast-changing standards and upgrading designs as new communication protocols appear on the market.

KEYS TO SUCCESS

In technological terms

- Optimise the command-control functions by decentralising them as much as possible to the intelligent actuators.
- Automation based on topology and safety.
- Complete integration between equipment items to guarantee optimum utilisation of the information.

Questions to ask

- Rethink the design, operation and maintenance of the facilities, including the ergonomic aspects.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 59

TECHNOLOGIES FOR REDUCING ENERGY CONSUMPTION

DESCRIPTION/DEFINITION

France has set itself the target of reducing its fossil fuel energy consumption by 30% by 2030, and its final energy consumption by 50% by 2050. Alongside this, the energy transition law stipulates that by 2030, renewable energies will account for 40% of the electricity produced and 38% of the final heat consumption. The European directive 2012/27/EU also sets a legislative framework for energy efficiency. The mechanical engineering industry and the factory of the future are obviously impacted by these targets. Many start-ups and SMEs are thus positioning themselves in energy efficiency, which designates the state of a system whose energy consumption is minimised for a given equivalent service rendered.
Energy efficiency can be passive (insulation, etc.) or active (energy measurement and management system, etc.). In the Industry of the Future's vision, the processes will intelligently manage several sources of energy (solar, wind turbine, recovered heat, etc.) and in some cases will be able to produce energy. Reducing the energy consumption of production sites requires, among other things, energy optimisation of the industrial premises and of the environment conditioning systems, reduction of the consumption of the production processes (control of the process, optimised flow management, etc.), improvement in the energy efficiency of the production equipment (machine tools, furnaces, treatment baths, etc.) and recovery of the unavoidable energy.

The following technologies and practices contribute to the energy efficiency of the Industry of the Future, among other things.

- For lighting:
  - > presence detectors on the lighting devices;
  - > high-efficiency T8 fluorescents lamps, control of lighting (light meter measurement, replacement plan, location of lighting points, etc.).
- For fluids:
  - > detection and suppression of fluid leaks (water, air, etc.) ;
  - > economisers on the gaseous effluents from steam production boilers;
  - > control of hot water (no heating during off-peak hours for example).
- For buildings:
  - > control of heating of the premises (optimised surface area, ceiling height, energy source, regulation, head losses in pipes, etc.) ;
  - > thermal insulation, insulation of pipes.
- For the machines:
  - > optimise the systems according to the application rather than the components considered individually;
  - > heat recovery from the compressed air compressors;
  - > implement real-time monitoring of energy consumptions.

ISSUES (BENEFITS)

In economic terms

- The energy savings translate directly into economic gains.
- The display of a reduced CO_2 footprint for the manufactured products can constitute a marketing argument.
- According to a European Commission study, the return on investment time for the energy efficiency measures implemented in industry is about 2 years.

In technological terms

- Most of the technologies associated with energy recovery are known, even if their applications remain poorly developed.

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TECHNOLOGIES FOR REDUCING ENERGY CONSUMPTION

In terms of business transformation

- The development of new manufacturing technologies (additive manufacturing, robotisation, etc.) implies changes in the company's energy paradigm.

In environmental and societal terms

- Energy optimisation can be achieved on a large scale, in a business activity zone for example, in order to optimise energy recovery, in the chemical industry in particular.

KEYS TO SUCCESS

In technological terms

- Develop the diversity of energies (renewable and conventional) and their storage in the industrial sector applications.
- Optimise process control and regulation from the energy viewpoint.
- Recover the industrial unavoidable energies.
- Develop heat recovery technologies.
- Optimise the behaviour of systems through the development of mechatronics.

In digital terms

- The increase in the volumes of exchanged data has a direct impact on the energy consumption of the servers. The heat recovery technologies are applicable in particular to computer and server rooms. The use of cloud computing also enables part of the energy consumption associated with digital processes to be outsourced.

In terms of skills to be mobilised, knowledge and training

- Make the energy performance of the organisation visible to the relevant decision makers. In large companies, the hierarchical distance between the persons in charge of the energy problems and the decision makers can make the processes long and arduous.
- Evaluate the exact energy requirement before investing in new equipment.

Questions to ask

- How can energy price fluctuations be taken into account when making an investment to control energy consumption?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 60

HIGH-PERFORMANCE WELDING TECHNOLOGIES

DESCRIPTION/DEFINITION

High-performance welding technologies refers to either disruptive solutions (as yet little used industrially but destined to develop significantly, such as friction stir welding or magnetic pulse welding), or sustaining technologies that have undergone significant changes, thanks in particular to developments in the area of power electronics (MIG-MAG welding, hybrid laser-MAG welding, for example).

Main applications of these technologies:
Welding is today an innovative assembly technique that is used in all sectors: automotive, aeronautics, rail transport, energy, nuclear, etc.

- Friction stir welding process: used for the construction of aircraft fuselage components (an increasingly widespread application), launch vehicles (rockets), ship decks, certain automotive parts. The very large majority of these industrial applications concern aluminium alloy parts, but a few applications with copper also exist.
- Magnetic pulse welding is a "cold" process that is particularly suited to the automotive industry, due to the numerous tubular parts and the ability to make multi-material assemblies
- Hybrid laser-MAG welding process: used in shipbuilding (welding of steel panels), in the automotive industry, in welded constructions, in the railway industry. Welding machines are improving and becoming simpler to use (hybrid laser-arc).

Main technological segments concerned:
Friction stir welding (FSW), laser welding, hybrid laser-MAG welding, magnetic pulse welding, brazing and diffusion-welding techniques, conventional fusion welding techniques (without gas shielding, in protective atmosphere, in vacuum).

ISSUES (BENEFITS)

In economic terms

- In a cross-cutting manner, the aim of the high-performance welding technologies described in this sheet is to offer significant savings in cycle time and increase the reproducibility of assembly operations by automating the process.
- Friction stir welding: no addition of material, no joint preparation, low electrical power consumption.
- Reduction in weight by eliminating rivets or by limiting the thickness of the assembly.

In technological terms

- High mechanical strength of the weld.
- Solid-state welding processes can be used to assemble metallic materials whose melting points differ greatly (welding aluminium to stainless steel).
- Friction stir welding: welding together several grades of aluminium (no hot cracking or porosity), heterogeneous assemblies.
- Magnetic pulse welding: production of homogeneous and heterogeneous solid-state assemblies and at high speed.

In environmental and societal terms

- Magnetic pulse welding: this technology produces no heat, light radiation, gases or fumes, and it consumes little energy.
- Friction stir welding: no emission of fumes and no consumables (raw material savings).

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HIGH-PERFORMANCE WELDING TECHNOLOGIES

KEYS TO SUCCESS

In technological terms

- Hybrid welding: cost of investment mainly due to the laser technology > €250 K, many more operating parameters to set.
- Development of robotic FSW to limit the cost of the machine investment and to have a tool with a real 3D capability.

In terms of skills to be mobilised, knowledge and training

- Lack of knowledge of these processes and their ability to provide new and effective solutions.
- Complexity of setting the operating parameters.
- Necessity to train design office personnel in these new technologies, in order to (re)design parts optimally for the chosen process.

Questions to ask

- Qualification of the procedures (international standards under preparation, very well advanced for FSW and hybrid laser-MAG welding).
- The health and safety constraints must be considered: very strong magnetic fields inherent to magnetic pulse welding and the hazardous light radiation used in laser and hybrid laser-MAG welding.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	**Mature**	**Frequent**	Pervasive

FACT SHEET 3

NOMADIC INDUSTRIAL APPLICATIONS

DESCRIPTION/DEFINITION

The Industry of the Future will be mobile with surveillance, remote control of machines and processes and performance optimisation in real time. Remote connectivity with automated production systems will become a fundamental requirement for the competitiveness of all manufacturing industry and processes. In fact, the ability to monitor, control and perform diagnoses of systems quickly will be essential. Remote surveillance will make the localisation of equipment and staff much more flexible, leading to a reduction in costs, improved efficiency and greater versatility to adapt to internal changes and external trends.

The arrival of mobile applications and access to *data via* different peripherals will also bring about a new mobility in human resources. Digital services are rising successfully to the challenges presented by mobility and are rapidly evolving towards increased compatibility, continuity and uniformity. In fact, global interoperability standards are emerging, such as OPC UA, making it possible to connect equipment and systems produced by different manufacturers. New tools will progressively address the problems associated with BYOD (*bring your own device*) development. BYOD must remain easy and simple to ensure that new generations of workers are able to use them.

Nomadic industrial applications therefore open the door to the arrival of numerous intelligent systems such as performance management systems, remote control and surveillance systems, control systems for buildings, infrastructural energy management and the optimisation of vehicle fleet use, etc.

ISSUES (BENEFITS)

In economic terms

- Remote operation and optimisation centres can be created. They are able to coordinate and optimise production and improve the energy efficiency and reliability of industrial sites by:
  - > predictive equipment maintenance;
  - > improvement in terms of operational productivity and performance.
- Nomadic applications increase the power of the digital revolution by making it possible to reduce costs, increase the lifespan of assets and improve operational efficiency.
- Tablets and smartphones have become financially affordable and some applications are now free to download.

In technological terms

- The convergence of many data automation and communication technologies makes it possible:
  - > to extract, analyse and manage data coming from sensors and similar components (explosion of the Internet of Things);
  - > integration of sensors with surveillance abilities into a process control system;
  - > remote learning and/or configuration functions;
  - > planning, coordination and implementation of corrective actions and preventive maintenance activities.
- *Via* immersive and virtual reality technology:
  - > decentralisation of training and maintenance
  - > improvement in transmission;
  - > development and maintenance of the desire to learn.

FACT SHEET 3

NOMADIC INDUSTRIAL APPLICATIONS

In terms of business transformation

- Mobile applications make it possible to create an organisation able to acquire the speed, agility and openness to integrate new technological opportunities intelligently.
- The introduction and distribution of new digital technologies in production sites and daily work (3D scan, augmented reality, tactile tablets, etc.) are made easier.
- Open innovation approaches between production site and the associated ecosystem teams are optimised.

In environmental and societal terms

- Environmental impact is reduced as a result of fewer physical journeys if nothing else.
- Modern image of the business that attracts a young population towards new industry professions.

▸ KEYS TO SUCCESS

In technological terms

- It is necessary to ensure greater compatibility between the various mobile technologies on the one hand and between these technologies and sedentary computer applications on the other.
- This development must absolutely occur in a robust, reliable environment that exploits the very best of the cloud and virtualisation.

In digital terms

- The key to success is the quest for ease of use, power, connectivity, security and cost monitoring:
  - > approach the user experience from an ease-of-use angle;
  - > provide the business with a terrain that is conducive to the creation of new uses and new areas of business.
- It is important to be vigilant in terms of cost and to have an understanding of the advantages in order to ensure that the investment is worthwhile.

In terms of skills to be mobilised, knowledge and training

- Expertise in big data and data sciences: these are two emblematic areas of digital transformation.
- The birth of new professions: real-time coordinators, analysts who study the production and the optimisation of consumption.

The questions to ask

- What level of remote coordination is necessary to bring about performance optimisation and the reduction of the risk involved in remote management?
- What is the compatibility between existing infrastructures and the upgrading of equipment that needs to be carried out?
- Am I knowledgeable about the accessible performance gains and the indirect impacts linked to the implementation of the latest technological innovation in the field of digital services?
- It is important not to forget questions linked to cybersecurity during the integration of technologies and mobile applications.

FACT SHEET 3

NOMADIC INDUSTRIAL APPLICATIONS

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

USEFUL LINKS

Editor: Office
Contributors Cetim, Gimélec

FACT SHEET 5

ROBOTIC COLLABORATIVE APPLICATIONS

DESCRIPTION/DEFINITION

Over the last twenty years, robotics have become much more widespread in industry. Originally developed to be autonomous with a view to replacing humans and performing difficult or tedious tasks, today they are becoming collaborative. The arrival of a new market segment is evidence of this: collaborative robotics.

The distinguishing feature of a "collaborative robot" is not to replace humans, but to work in tandem with them. To develop a machine of this kind, it is essential to consider the ergonomics of the interaction between the robot and its user from the design phase.

Collaborators or co-actors, robotic collaborative applications make it possible to robotise production situations that couldn't previously be robotised because the cycle time was too low.

It is possible to identify several families within robotised technologies, depending on the intensity of the interaction between robot and human. Robotic collaborative applications deal with situations of co-existence and collaboration.

The challenge lies in the human/machine interface and the ergonomics of the robotised system. There is a double objective: preserving health at work while improving performance, and adapting the system to reflect human characteristics, making it possible to use the robot whether you are a child, adult, experienced or inexperienced.

ISSUES (BENEFITS)

In economic terms

- Reduction in production costs, which in turn makes it possible to avoid outsourcing, and indeed to envisage repatriating previously outsourced processes.
- Easy to programme and integrate in proximity to humans, can be adapted in small numbers to reflect increasingly diverse customer requirements and preferences, at a reasonable level of investment.

In technological terms

- Precisely define requirement specifications for the integrator.
- Favour versatility of robots over overly specialised machinery.
- Do not robotise a process that is not yet fully mastered.

In terms of business transformation

- Construct a genuine industrial strategy and an associated communication plan around five inseparable pillars: business (profitability, turnover), production (performance, quality), integration (processes, information system, evolution), regulatory requirements (directives, standards) and the human aspect (incentive, work conditions).

In environmental and societal terms

- Reduce human operators' exposure to the risks associated with physical limitations, aggressive environments and unpleasant working rhythms.
- An integral part of industry of the future and its vision which places humans within the heart of the factory.

FACT SHEET 5

ROBOTIC COLLABORATIVE APPLICATIONS

KEYS TO SUCCESS

In technological and digital terms

- Choose the best solutions with regard to our future production systems, human factors and technological advances.
- Enlist support and implement a methodology for introducing robotic collaborative systems.
- Find a good balance between the robot's ability, ergonomics, security and cost.

In terms of skills to be mobilised, knowledge and training

- Implement a methodology that makes it possible to conceive and design collaborative robots and the interface that will make it possible for them to interact with their user, with a view to it being accessible to all in terms of use:
  - > the operator is integrated into this methodology. Not only in terms of training, but also from the interactive robotised system design in order to ensure the optimal allocation of tasks to the human operator and the machine.
- Offer a personalised training plan so that each operator knows how to work with the robot in maximum safety conditions.

The questions to ask

- Offer a personalised training plan so that each operator knows how to work with the robot in maximum safety conditions.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 10

COBOTS AND EXOSKELETONS

DESCRIPTION/DEFINITION

Cobots have been developed as a result of the desire on the part of manufacturers to reduce muscular-skeletal problems on production lines / chains and to improve working conditions. The technology can be used in different ways: finalising, inspection, handling, etc. Cobots are designed to reconcile human flexibility and robotic performance in total security.

The following definitions make it possible to contextualise cobots effectively:

- a **robot** is a way of automating an activity. It therefore doesn't require the intervention of a production technician. The human operator and robot can co-exist while carrying out two different work-related tasks, the robot working in isolation (enclosed in a secure area);
- a **collaborative robotic system** implements a robot that has been specifically designed to work with the operator, or next to him/her, in complete safety. The robot is equipped with all the necessary technologies to ensure the complete safety of the human operator without being enclosed;
- a **cobot** assists the operator like an effort amplifier with information feedback. The human operator manipulates it with their arm. It has no autonomy whatsoever;
- an **exoskeleton** is a robot that is worn by the operator. It can assist the lower members, upper members or both. Most frequently, it is worn to reduce the physical effort required by the operator during handling operations, for example. It can also help to hold the operator in a static position.

ISSUES (BENEFITS)

In economic terms

- The primary objective of cobotics is not to increase the volumes produced, but it can provide a certain reliability in the execution of manufacturing processes. The introduction of cobots will make it possible to improve industrial performance by increasing in flexibility thanks to their mobility (there are no fenced-in cells) and also to increase productivity and quality by going beyond the limits imposed by human ability. In certain cases, a cobot could carry out the work of several operators.
- Economic advantages associated with the reduced work-related illness and accidents.

In technological terms

- Reduction in human error and increased reliability.
- Increase in human abilities.
- Implementation of secure procedures to assist in human/machine-based work.
- Handling of parts with characteristics that are incompatible with direct human handling (radiation, heat etc.).

In terms of business transformation

- Compliance with regulatory requirements and policy initiatives.
- Investment in risk prevention.

In environmental and societal terms

- Improvement in working conditions: cobotics will make it easier to carry out difficult and repetitive tasks (sanding, for example) which can lead to muscular strain injury or work-related accidents. For information purposes, work-related accidents equate to 1 billion euros in terms of days

COBOTS AND EXOSKELETONS

that are reimbursed by the French social security system (mainly for muscular strain injuries) and 2.5 to 3 times more in terms of loss of productivity for businesses.

- Appearance of new positions and reduction in positions that are referred to as "difficult". The result of this will be that employees will become more skilled at performing higher-added-value tasks and will enhance their work.

KEYS TO SUCCESS

In technological terms

- Mechanical, electrical, electronic and software integration.
- Increased precision of movements.
- Lower energy consumption.

In digital terms

- Creation of high-added-value software making human operator / machine work possible in a secure manner.

In terms of skills to be mobilised, knowledge and training

- Training in the use of cobots and exoskeletons with the dual purpose of reassuring the operator in terms of ease of handling and teaching the operator to work with the cobot in the most effective manner possible.
- There are no particular skills required to use a cobot, but it is essential to have a thorough understanding of the different technologies involved for maintenance purposes.

The questions to ask

- Are there any roles in my company that require challenging positions or postures or significant muscular effort?
- Could some workstations be accessible to vulnerable people with a weak constitution, older people or people with disabilities?

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

FACT SHEET 33

OPEN AND COLLABORATIVE INNOVATION

DESCRIPTION/DEFINITION

For a company wishing to broaden its field of development, collaborative innovation means joining up with other partner organisations (businesses, research organisations, technical centres, Carnot Institutes, etc.) to encourage the emergence of, decide on and/or create one or more innovative projects in a collective manner. Innovative collaboration requires that these partners agree on intellectual property, risk sharing, pooling resources and the division of profits resulting from the innovation project(s) that are the aim of the partnership. The collaborative innovation projects are, more often than not, driven by a consortium supported by a competitive cluster, or are in response to a call for collaborative projects by a financial support public organisation (PIAVE, FUI, Bpifrance, ADEME, H2020 of the European Commission, etc.), although they can take place in a private context, between businesses or between a business and a research organisation (most frequently occurring examples) who draw up a contractual agreement to formalise their collaboration.

We refer to open innovation when an organisation:
- seeks ideas and expertise externally to extend their own expertise;
- makes their own experience and patents available.

We can distinguish:
- *scouting*: looking for (an) existing solution(s) to a problem or, conversely, looking for new applications for a technology beyond any geographical, cultural, scientific or technical boundaries in place;
- *crowdsourcing*: seeking the input of a community of a certain size in order to collect new ideas and solutions. This kind of request is frequently presented as a challenge which is open to the general public or on a more restricted basis.

ISSUES (BENEFITS)

In economic terms

For collaborative innovation:
- For businesses whose offers are complementary, the benefit in joining forces is to strengthen their position and to gain market shares. For an SME, associating with a client on an innovation project constitutes an undeniable sales strength, which imparts a competitive edge enabling them to be in a favourable position to sell the product or service resulting from this collaboration on the market. Sharing between partners enables each partner to have an overview and understanding of a wider market.
- The company benefits from a reduction in *time to market* as well as a reduction in risks due to the sharing of these risks.

For open innovation:
- Open innovation may be a suitable response at a time when budgets dedicated to innovation are being cut. Open innovation make is possible to multiply ideas. However, investment is necessary to manage *open innovation* and for the use of an innovation that is the property of another company (licences, royalties, etc.).

In technological terms

For collaborative innovation:
- For SMEs, this kind of partnership makes it possible to access skills and technology that they do not own, in France and/or internationally. This kind of approach can also be profitable for an MSB or a big company in order for them to take on a high-risk innovation to maintain competitiveness.

FACT SHEET 33

OPEN AND COLLABORATIVE INNOVATION

In digital terms

For open innovation:

- The use of certain dedicated web platforms makes it possible to find a solution provider who may be on the other side of the world and previously totally unknown. This expert may be a start-up, a scientist... Or an enthusiast with some scientific background and suitable tools.

In terms of business transformation

For collaborative innovation:

- The management of a collaborative project requires skills and resources which are most commonly found in large companies, a research organisation, a technical centre, etc. Generally, SMEs use the support of these external resources. As a result of pooling resources, collaborative projects present advantages (cost reduction of a project, risk reduction, speeding up of the innovation process), which may appear to be disadvantages when the consortium is made up of too many partners (leading to weighty, slow administrative procedures).

In environmental and societal terms

For collaborative innovation:

- Working together, between organisations with different cultures and activities, represents progress and wealth in human relations.

- Collaborative projects make it possible to tackle environmental challenges. On the one hand, these issues are new challenges, whose horizon can sometimes be far off, which lends itself particularly well to risk sharing. On the other hand, public calls for projects very often include selection criteria that encourage the response to environmental issues.

► KEYS TO SUCCESS

In technological terms

For collaborative innovation:

- Being able to access a new, enabling technology for the intended application.

For open innovation:

- The nature of the technical need made available online and its formulation are extremely important. They must be chosen with a great deal of care. A complex need can be broken down into several themes, which will be made available online to ensure their anonymity and limit the leak of ideas.

In digital terms

For collaborative innovation:

- Innovative collaboration is promoted through the existence of digital tools or platforms that make it possible for several key players to work together and to interact in a simultaneous manner on the same innovation project.

For open innovation:

- Many tools are available to support *open innovation*, with different final objectives:
  - creative tools to generate ideas drawing on the input of staff at all levels of the company; these tools can then be used to select, develop and validate by simulation.
  - open modelling and simulation platforms to validate concepts;
  - platform with a semantic engine to find out about existing R&D projects or projects;
  - platform made available to experts or companies.

FACT SHEET 33

OPEN AND COLLABORATIVE INNOVATION

In terms of skills to be mobilised, knowledge and training

For collaborative innovation:

- Joining forces with partners who have the necessary skills.

For open innovation:

- Many tools can facilitate *open innovation* within a company, such as internal social networks and collaborative innovation platforms.
- The use of an *open innovation* platform is not risk-free. There can be problems around confidentiality and intellectual property (as much around the protection of a company's skills as around the rights attached to the proposed solutions). Careful attention must be paid to the choice of "experts" referenced on the open platforms.

The questions to ask

- Has the company identified the resources required for the future innovation projects that it intends to carry out?
- Which innovation projects would the company benefit from carrying out alone and which projects would it be better to carry out in partnership?
- Are the company, managers and employees sufficiently involved in the innovation networks and ecosystems to be able to identify attractive partnership possibilities?
- Is the consortium balanced, with the number of partners not too high to result in usable results?
- Clearly define the sharing of intellectual property and conditions of use before collaborating.

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

FACT SHEET 52

AUGMENTED REALITY

DESCRIPTION/DEFINITION

Augmented reality helps operators to perform their tasks by providing them in a simple way with the information that they need in their field of vision (for example, the visualisation of KPIs of machines by simply looking at the machine through augmented reality glasses). It is considered as an interface between "virtual" data and the real world (source: Association de promotion de la réalité augmentée - Association for the promotion of augmented reality) by superimposing virtual data onto the real world in real time *via*peripherals. Augmented reality systems are designed to improve the perception of the world that surrounds the user and to facilitate their interaction with it.

Main applications of these technologies: more than application markets, it is important to discuss the uses that develop in a cross-functional manner across all sectors: remote information sharing, use for design (products, productions systems), for remote training, for maintenance, for security and remote intervention. As a result, these technologies and uses are clearly visible in the car industry, aeronautics, railways, energy, oil and gas, medicine, agribusiness, construction and even in the consumer goods sector (tourism, luxury, accommodation, furniture, etc).

Main technological segments affected: assisting operators in their task, peripherals (immersion headset, active gripper for haptic devices, tablets, etc.).

ISSUES (BENEFITS)

In economic terms

- Increased efficiency of maintenance operations thanks to augmented remote support.
- Reduced training cycles and the time taken for decision-making.
- New experience of context-based product sales.

In technological terms

- Miniaturisation of heads-up display devices.
- Combination with natural language processing technologies and *data mining*.
- In terms of business transformation
- Access to all information systems data in operations locations.
- The expert in question is no longer required to be on site during urgent maintenance operations thanks to augmented remote support.

In environmental and societal terms

- Augmented remote support: reduction in transport costs associated with ecological impact.
- Augmented publicity: more immersive and paperless content (reduction in consumption and paper-based pollution).
- Reduction in costs associated with the return of unsatisfactory merchandise, thanks to virtual trialling in context.

FACT SHEET 52

AUGMENTED REALITY

KEYS TO SUCCESS

In technological terms

- Rapid changes in materials and tools offers.
- Interaction with data *via* an augmented reality device is still complex in hands-free mode (requirement for intelligent interfaces based on gesture and word recognition).
- The spatial positioning of the device in its natural environment remains tricky (depending on light conditions or other).
- Systems modelling: need to bear in mind the anticipated levels of performance and operator practices.
- The simple and direct use of CAD models and automation of their simplification for real-time.

In digital terms

- Improvement in the resolution and precision of models.
- Quality of HMIs and ergonomics to facilitate adoption of these technologies and to facilitate change management, technical problems specific to digital continuity.

In terms of skills to be mobilised, knowledge and training

- Training of support, customer service and maintenance teams.
- In parallel, augmented reality makes it possible to deal with skill shortages in certain operator or technician roles thanks to augmented remote support or tutorials.
- Preparation of data upstream from project reviews (significant adaptation and sometimes the development of CAD model-based scenarios).
- Proficiency in development kits specific to augmented reality.
- New educational methods to be implemented as a result of the scope of augmented reality.

The questions to ask

- The financial aspects involved in the evaluation of an ROI, which plays a crucial role in the choice of applications for the integration and effective use of these new technologies.
- Impact of emerging technologies (machine learning, quantum computing).
- Development in promising markets, particularly “at-risk” industries (oil and gas installations, nuclear power plants, mines, etc.)
- How best to take into consideration aspects of data protection and confidentiality?
- Acceptance by the general public to wear a heads-up device increasingly frequently.

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

FACT SHEET 53

VIRTUAL REALITY

DESCRIPTION/DEFINITION

The aim of virtual reality is to make a digitally created artificial world, which may or may not resemble a real world, appear to a user and to give the user the opportunity to interact intuitively and naturally with this world [source: Centre de réalité Virtuelle de la méditerranée - Mediterranean Centre for Virtual Reality]. Virtual reality consists of a combination of different technologies which, on one hand, capture the user's movements, making it possible for them to interact by means of their avatar and on the other hand, recreate for the user the effect of their avatar's interaction with the virtual environment by means of sensory interfaces (images, sound, force feedback, etc.). These technologies consist of real-time mechatronic interfaces and graphical interfaces. Virtual reality tools and software in connection with CAD tools and software make to-scale interactive visualisation possible within the context of the use of products still in the design phase of development.
In factories, virtual reality will make it possible to improve the learning of tasks in terms of time and quality and the qualification of the ergonomics of workstations.

Main applications of these technologies:
More than application markets, it is important to discuss the uses that develop in a cross-functional manner across all sectors: the learning of complex tasks in preparation for a real situation (emergency or maintenance operations simulation, for example), qualification of the ergonomics of workstations (impact on operator work conditions and productivity), assistance in the assembly design and validation during project review, and sales support tool. As a result, these technologies and uses are clearly visible in the car industry, aeronautics, railways, energy, oil and gas, medicine, agribusiness, construction and even in the consumer goods sector (tourism, luxury, etc.). In an industrial context, it is possible to envisage the digital twin of the real factory, making it possible to use connected objects to support the life of the factory and by using virtual reality as a means of conveying information to the user.

Main technological segments affected:
Immersive virtual reality, natural interaction, 3D immersion, haptic feedback, interfaces that reduce immersion sickness, browsing tools (software or hardware), use of immersive rooms, data preparation and scene-setting.

ISSUES (BENEFITS)

In economic terms

- Tool to support sales: improvement of the image of the company and products by offering an immersive experience in the future product (journey, building, apartment or car, for example).
- Virtual validation of the assembly or technical installation: reduction in development timelines and in risk of error during construction.

In technological terms

- Improvement in the quality of immersion and reduction in nausea.
- Rapid technological developments in virtual reality devices worn by the general public market.

In terms of business transformation

- Involves all departments in a company in the design of a product: marketing, maintenance and research and development.
- Development of co-creation by involving the customer, distributors, etc. as early as possible.
- Immersive work session and conferences: reduction in travel and a change in habits relating to remote meetings.

FACT SHEET 53

VIRTUAL REALITY

In environmental and societal terms

- Virtual prototyping: virtual reality reduces or even eliminates the creation of superfluous products (economising on raw materials).
- Reduction in storage and transport costs with their associated ecological impact thanks to virtual trialling.
- Virtual publicity: more immersive and *paperless* content (reduction in consumption and paper-based pollution).
- Remote analysis of the environment with a 360° camera, making it possible to explore a location without disturbing it (research work, tourism).
- New awareness-raising engine: humanitarian crises, global warming.

▸ KEYS TO SUCCESS

In technological terms

- Systems modelling: need to bear in mind the anticipated levels of performance and operator practices (it isn't always necessary to be as close as possible to the real object).
- Direct use of CAD models that often have to be reworked to guarantee real-time.
- Deployment of software solutions that are compatible across multiple formats (headsets, CAVE, etc.).
- SNUI (super natural user interface) access to technology and "sensory" interaction with the computer.

In digital terms

- Quality of HMIs and ergonomics to facilitate adoption of these technologies and facilitate change management, technical problems specific to digital continuity.
- Evolution towards "mixed reality" or "augmented virtual reality" that fuses the real and virtual worlds.
- Improvement in avatars and user experiences in the context of collaborative sessions.

In terms of skills to be mobilised, knowledge and training

- Preparation of data upstream from project reviews (significant adaptation and sometimes the development of CAD model-based scenarios).
- Proficiency in development kits specific to virtual reality and of new offers integrated with design tools.
- New educational methods to be implemented as a result of the scope of virtual reality.

The questions to ask

- The financial aspects involved in the evaluation of an ROI, which plays a crucial role in the choice of applications for the integration and effective use of these new technologies.
- How long will it be before virtual reality is widely accepted by the general public?
- Unresolved questions on the long-term physical and mental health effects of exposure in subjects (young people, factory operators).
- How can we protect data? What is the most ethical way to collect operator data?

FACT SHEET 53

VIRTUAL REALITY

MATURITY OF THE OFFER

- The software offer is currently very fragmented and may lead to a possible breakdown in digital continuity.
- Big publishers are developing their native ability to integrate virtual reality into the heart of their design tools.

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

USEFUL LINKS

Contributors Arts et Métiers (Frédéric Mérienne, LISPEN Institut Image)

FACT SHEET 8

CLOUD AND BIG DATA

DESCRIPTION/DEFINITION

Cloud computing is an IT system for data and services that is accessible via Internet. The "cloud" refers to a set of processes that use the computing power and/or storage capacity of remote servers via a network, generally the Internet. These servers are rented on demand, usually per period of use according to technical criteria (power, bandwidth, etc.) or for a fixed price.

Big data is the result of the explosion of the amount of digital data in existence, which has led researchers and analysts to come up with new technological and organisational means of analysing and exploiting them. Big data is generally stored in the cloud, which – by virtue of its data collection, storage, and easy-access capabilities –constitutes an adequate tool for the quantitative and qualitative multiplicity of data. It allows hidden trends to be detected, can be used to carry out predictive analyses, and enables greater efficiency.

ISSUES (BENEFITS)

In economic terms

Interconnecting the production sites and departments within a company requires the sharing of large amounts of data, which is facilitated by the cloud. Indeed, the cloud can be particularly useful to supply chains because it allows the following:

- creating cooperative links between multiple locations;
- viewing gains in productivity, etc. on a dashboard;
- shorter time-to-market;
- faster response to customers' changing needs.

What big data allows is identifying economic gains that can be achieved using concepts such as data warehousing (to rank data), data visualisation (to analyse them), business intelligence and predictive analysis.

In technological terms

The presence of sensors on machines and products allows an enormous amount of data to be collected and analysed. With the right processing and analysis tools, this data enables the following:

- a better understanding of the operation of complex devices by comparing virtual data with data from real-world conditions (digital twin notion);
- qualifying equipment using virtual or hybrid test tools ("hybrid" meaning combining virtual tests with test benches);
- cataloguing, monitoring, and optimising the production chain;
- extending machine life through preventive maintenance actions made possible by anticipating failures.

In terms of business transformation

- The secure industrial cloud allows all businesses, especially SMEs, to benefit from adapted and upgradeable software (business applications, PLM, MOM, ERP) without needing to purchase high-range hardware or install complex software.
- Big data analysis can provide manufacturers with feedback on how their products are used, which they can then take into account in designing the next generation. New commercial models such as on-demand use and or pay-per-use billing are going to lower the holding cost, significantly improving the return on investment for equipment and freeing up capital.

FACT SHEET 8

CLOUD AND BIG DATA

In environmental and societal terms

Big data analysis leads to reduced energy consumption. Indeed, it allows all of the variables from all of a site's information systems (energy, production, quality, etc.) to be collected and analysed in order to define the optimal energy settings for processes.

KEYS TO SUCCESS

In technological terms

- Manufacturers generate turnover by selling their machines, but also by offering new services.
- Knowledge and use of big data collection and processing tools (NoSQL databases, massively parallel processing (MPP), key-value stores or Memtables, HADOOP/MAPREDUCE, etc.).
- Big data is based on five key elements, the "5 Vs", to be taken into account:
  - **Volume:** the amount of data to collect and analyse is vast and constantly expanding;
  - **Velocity:** the speed at which data is created and processed, and the speed at which I need to analyse it for it to be useful to my company;
  - **Variety:** data can take many different forms and be extremely diverse (voices, facial data, transactional data, web analytics, texts, images, etc.);
  - **Veracity:** data veracity or reliability can be compromised by reporting behaviours (on forms), diversity of collection points, multiplicity of data formats, and activity by robots and the innumerable fake identities rampant on the Internet;
  - **Value:** in an age of information overload, the challenge is to focus on the data that are operable and of real value.

In digital terms

Adopting new security and backup standards, to be handled with IT service providers. The cloud includes SaaS (*Software as a Service*), PaaS (*Platform as a Service*), IaaS (*Infrastructure as a Service*), etc.

In terms of skills to be mobilised, knowledge and training

- Using the cloud requires an increase in operational expenses with regard to capital spending.
- Staying up to date on new standards and knowing how to apply them.

Questions to ask

- Are my data secure? Using the cloud and big data requires monitoring data security.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

SHEET 9

INNOVATIVE NDT

DESCRIPTION/DEFINITION

European industry today is trying to produce increasingly lighter components while maximising their service life and reliability. The high costs of security and maintenance have encouraged the development of non-destructive testing methods capable of detecting defects as early as possible, both on the production line and in equipment in service. The growing focus on ensuring the reliability of analysis methods and procedures has led to the development of many NDT (non-destructive testing) simulation tools and mathematical models. New areas of research are also emerging in order to provide more information on NDT technologies while also increasing the economic value of inspections carried out by incorporating this information into a high-quality context.

A wide range of modern NDT technologies will be used as part of the industry of the future. They are based on the development of new methods for signal processing and digital imagery as well as on the evolution of sensors (with or without contact). The main innovative NDT methods (imagining that they will be linked within multi-physics/multi-sensor NDT systems) are the following:

- acoustic systems (intensimetry, beamforming, holography, interferometry);
- inductive systems;
- optical systems (laser beam, semi-conductor/LED, holography, new terahertz radiation, etc.);
- infrared thermography (thermal and/or near-infrared hyperspectral to millimetre-wave infrared):
- NDT paired with robotics (robotised instruments: machine vision on production lines, fixed instruments and moving parts);
- 3D X-ray tomograpy
- IR sensors (spectroscopy) for multi-layer/blend monitoring;
- Eddy currents and multi-element ultrasound and/or thermal detection;
- technologies for inspecting micrometre and/or multi-scale parts (micron to metre);
- liquid analysis technology (viscometer for polymer/nanofiller composites, calorimeter for chemical reaction monitoring, Raman spectroscopy).

ISSUES (BENEFITS)

In economic terms

- Innovative NDT methods, in particular multi-element NDT systems (multi-sensor, multi-physics, multi-scale) cut costs thanks to the time saved on sensor adjustment and data acquisition.

In technological terms

- Non-contact measurement technologies (e.g., optical/laser) allow NDT to be inserted into industrial processes: the measurements can be applied to a wide range of materials regardless of surface condition (soft, fragile, hot, acidic, etc.) and can be carried out continuously on moving parts or hard-to-reach components.
- For acoustic or vibration applications, acoustic beamforming allows for remote noise source identification and location, and can therefore be used for remote vibrational characterisation on hard-to-reach or moving parts.
- Non-contact technologies offer greater operational safety, since the measurement is taken at a distance from the dangerous machine or process.
- Field analysis and digital image correlation (displacement field measurement on the surface of a deformed image compared to a reference image using CCD cameras) enable the powerful pairing of machine and robot vision. 3D analysis can be obtained using a combination of multiple cameras.

FACT SHEET 9

INNOVATIVE NDT

- Tomography methods allow analysis of the internal structure of complex parts (all types of materials, including composites).
- Digital imaging, when transmitted, can be used with the additive manufacturing process to improve the production of complex internal/external shapes.
- Eddy current or ultrasound NDT can be carried out using multi-element probes, including several sensors of the same type, thereby improving measurement accuracy while at the same time reducing the data acquisition time.

▸ KEYS TO SUCCESS

In technological terms

- Optical technologies must be adapted to the environment, as their performance can depend on the ambient conditions (temperature, humidity, droplets of water or oil in suspension, etc.).
- Research is being done to improve acquisition and calculating times in tomography. Better managing measurement uncertainty is another area for improvement. Moreover, some types of defects (cracks in joints, highly uniform materials) remain difficult to detect.

In digital terms

- For field analysis methods, it is necessary to implement means adapted to the long calculating times required for data processing.
- New NDT systems allow for the acquisition of large amounts of data (big data). The analysis methods must take into account data-reduction methods and at the same time, methods for reduction of physical models adapted to these data.
- Methods to aid decision-making must be adapted to the digital environment (data, analyses, models).

In terms of skills to be mobilised, knowledge and training

- Certain methods may require skill development, as in the case of expertise-oriented digital systems, for example.
- The widespread use of multi-element/multi-physics NDTs (Eddy currents or ultrasound) involves training operators.
- Non-contact measurements must be carried out in accordance with the new ISO 10-360 standards.

Questions to ask

- In the case of digital image correlation, how can we prepare for the arrival of the new AFNOR standard (planned publication of a pre-standard for a reliable and harmonised method)?
- How can we take advantage of the highly advanced research being done in academic laboratories?
- What intermediary structures exist between academic laboratories and industrial working environments (shared laboratories, technical centres)?
- How can we incorporate NDT solutions into a digital working environment?

FACT SHEET 9

INNOVATIVE NDT

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

USEFUL LINKS

Contributors: Arts et Métiers (Jean-Christophe Batsale I2M)

FACT SHEET 15

VIRTUAL DESIGN AND QUALIFICATION OF PRODUCTION SYSTEMS

DESCRIPTION/DEFINITION

Setting up a new industrial plant involves several stages: designing the production plant, preparing and overseeing the construction site, starting up and acceptance-testing the equipment, training the operators on the their workstations and the procedures, etc. All of these essential steps can be simplified by new virtual and immersive technologies. Virtual reality is a valuable tool at every stage in the cycle, with possible extension of its use to operations, after-sales service and maintenance. It has been shown to be an important factor in the collective intelligence process as a result of improved collaboration between all the company's sectors.

The first step involves viewing the industrial site in 3D before its creation, during the preliminary design phase. Viewing this 3D model is essential in facilitating faster decision-making, better controlling interfaces and making technical decisions more robust. For the customer, it provides a preview tour of their future facility thanks to the collaborative aspect of the interfaces. This presentation provides a view of all of the basic building blocks of a factory: building and infrastructures[1], manufacturing process, logistical means, etc.

Immersive technologies immerse the human in the factory milieu, allowing them to validate interactions between humans and their environment, and even to make the changes needed to meet the effectiveness, safety and ergonomics criteria. It also allows future tasks to be carried out in practice, in order to familiarise operators with the risks and hazards present on site, particularly in order to prevent certain accidental risks.

Later, these virtual and immersive technologies can help in training the first workers for the new production plant. Indeed, operators can be trained on their working environment while the plant is being built, in order to be operational from the first day the plant opens. Virtual and immersive systems can also be used after construction of a production plant for skill upgrading and booster trainings, training on at-risk operations, remote collaboration for difficult field operations, and as an aid in decision-making relating to improving a workstation's ergonomics.

Even though the cost of immersion centres remains high, and often out of reach for SMEs, the growing number of shared centres is making them more accessible, and the development of immersive applications with virtual reality headsets is helping popularise these technologies. A headset is perfectly suited to preparing scenarios carried out in individual exercises. The prepared content can then be shared *via* collaborative applications or in shared virtual reality rooms, for re-viewing by multiple people.

ISSUES (BENEFITS)

In economic terms

- It costs less to create virtual reality equipment than a workstation on an assembly line.
  - > Ensuring that every tool is well-designed from the start eliminates the need to make changes along the way or to scrap a costly production tool.
  - > Being able to test new configurations and incorporate flexibility and agility into the production tool.
- Enabling faster decision-making and more effective interface management.
- With regard to theoretical training on the production site:
  - > faster training time for personnel;
  - > reduction of risks on site;
  - > improved operational productivity.

1. Here, we are talking about BIM: *Building Information Modelling*, for example.

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VIRTUAL DESIGN AND QUALIFICATION OF PRODUCTION SYSTEMS

- With regard to practical training in interaction with the virtual environment:
  - > faster training time for personnel;
  - > reduction of risks on site;
  - > assurance of safety for personnel;
  - > optimised productivity on site.

In technological terms

- These technologies are mature enough for industrial use deployed in a systematised manner in development processes.

In terms of business transformation

- Professional development in all sectors, based on progressive digitisation of the entire *manufacturing* value chain.
- Ensuring that these technologies are adopted by all players in the value chain thanks to digital continuity between all the various virtual content.

In environmental and societal terms

- Optimising manufacturing and assembly operations has a direct impact on the energy and environmental performance of production tools and on employees' working conditions.

KEYS TO SUCCESS

In technological and digital terms

- The technologies (*hardware*) are now mature and available. The obstacles, mainly with regard to digitising and virtualising production tools, are gradually being overcome (adoption of digitisation, digitising means, etc.).
- The keys to success lie in deploying the right skills by identifying a short-term return on investment justifying a significant investment in this area.

In terms of skills to be mobilised, knowledge and training

- Thinking about how virtual reality can contribute to the evolution of both 1) training software; and 2) working instructions in production / maintenance workshops and warehouses.

Questions to ask

- Industrial players must consider the added value of these approaches, which in many situations enable significant improvements in terms of ergonomics, productivity and agility.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 16

PRODUCT DESIGN AND SIMULATION

DESCRIPTION/DEFINITION

In this era of connected objects, electronics and additive manufacturing, digital simulation is one of the key technologies in engineering. It involves creating a virtual study of a part or process based on different scenarios under study. Accessible to all businesses, of any size and any sector, digital simulation can be a tool allowing major technical advances and economic savings.

Advances in the performance of existing tools have broadened the scope of use for simulation: integrating it from the start of the design process allows the impact of changes to be examined in real time so that all possible options can be quickly explored.

Applications such as the digital mock-up or the integration of biomimetic criteria are gradually reaching maturity. Tools integrate a growing dimension of multi-physics, with facilitated use (multi-device, SaaS mode, etc.)

ISSUES (BENEFITS)

In economic terms

- Responding to all problems concerning the materials used, the products and the process.
- Optimising production parameters, reducing the weight of parts.
- Reducing development cost and time.
- Optimising the product's mechanical performance.

In technological terms

Simulation serving industry is a means of accelerating design and manufacturing phases. A number of innovative technological building blocks provide another dimension of simulation:

- virtual reality to allow players to understand and adopt future products by immersing them in the complete visual and functional environment of a product line;
- GPU acceleration to reduce the time needed to explore many design variables in order to optimise performance and stay on schedule;
- data science technologies allowing manufacturers to resolve and anticipate variability and instability phenomena with preventive maintenance applications thanks to the creation of digital twins of the products and processes;
- constant technological advances in high-performance computing (HPC), big data and the cloud, which are expanding the scope of use for digital simulation day by day, with the implementation of a portal and tools for remote viewing.

In terms of business transformation

- Transforming the vision of the company's product/customer pair, orienting it entirely towards the notion of usage, thanks to data on the use of products.

KEYS TO SUCCESS

In technological and digital terms

- Data assimilation for analysis and forecasting:
  - mapping available data and structuring the information system;
  - availability of a growing number of physical measurements for increasingly closer intertwining of digital simulations and data.

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PRODUCT DESIGN AND SIMULATION

- Quantification of uncertainties and comprehensive simulations:
  - > the increasing power of computers means a larger number of simulations of the same phenomenon can be undertaken, with random variations in the parameters that influence them;
  - > these experiments allow the uncertainties of a result to be quantified as a function of the uncertainties of the input parameter.
- Combining measurements and models using statistical considerations:
  - > closely linked to data assimilation and uncertainty quantification analyses that are based on comprehensive simulations;
  - > gradual comparison of the physical model and data processing.

In terms of skills to be mobilised, knowledge and training

- Advanced skills in all of the key areas of expertise relating to simulation: modelling and simulation, design processes, data sciences and predictive analyses, etc.

Questions to ask

- These relate to the impact of advanced simulation tools on company performance, in terms of its organisation, production or development.
- What are the implications in terms of profitability?
- What are the imperatives in terms of business continuity and digital transition?
- What investments are required (tools, HR, process transformation, etc.)?

► MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 29

PRODUCT QUALITY MANAGEMENT

DESCRIPTION/DEFINITION

To stay competitive, companies have to establish a strategy that allows them to generate better products faster and at lower prices than their competitors. The factory of the future will enable better quality management by evaluating it throughout its life cycle (design, production, use and destruction), in particular through technologies for detecting defects during production, for managing identification, for traceability and for geolocation of products and manufacturing operations.

Managing product quality involves in particular:

- setting up identification and traceability technologies (datamatrix, RFID, barcodes, NFC, active or passive tags, etc.);
- detecting defects in production (geometry, material soundness, automated NDT, 100% functional tests, etc.);
- geolocation of outdoor and indoor products;
- information management (logs, barcodes, etc.);
- integrating traceability into production software;
- anti-counterfeiting measures;
- traceability of products and manufacturing operations;
- keeping track of usage (*via* HUMS *Health and usage monitoring system*) in operation.

The major focus of quality must be listening to customers and taking their feedback into account. This means obtaining input into the approach through customer surveys, in order to collect their expectations and perspectives, to use them as a lever for change and to analyse the processes in view of the information collected. Quality must be based on a clearly defined framework while also encouraging initiatives. A certain amount of flexibility is a key element of Quality deployment. Dissociating the negotiable from the non-negotiable is essential.

Initiatives are aided and supported by a methodology that encourages setting up network-style leadership, recognises best practices, organises the comparison of performance with other companies and develops informal communication.

Realigning the “cost of non-quality” versus the “cost of obtaining quality” will be impacted by these new technologies that make it possible to do better at a lower cost, opening a wide range of possibilities.

ISSUES (BENEFITS)

In economic terms

- With regard to the purchase and sale of products, quality is one of the characteristics that generates confidence, therefore serving as a buying trigger. As such, managing the quality of the product and production tool processes is an essential element of the company's economic performance.

In technological terms

- Systems composed of inter-adapted machining centres, transportation systems and industrial robots enable competitive manufacturing in mass production while also meeting customer needs for customisation.
  - > Temperature, pressure, level and flow rate sensors for reliable monitoring of process fluids.
  - > Robotised units and assembly stations, multi-beam safety barriers, electronic safety guards and inductive safety detectors to protect machines and people.
  - > Inductive, capacitive and opto-electronic detectors and detectors for?? for precise detection of machine part positions.
  - > Vibration monitoring systems for conditional preventive maintenance for machines-tools.
  - > RFID systems, barcode readers and camera systems for equipment traceability and quality monitoring.

FACT SHEET 29

PRODUCT QUALITY MANAGEMENT

In terms of business transformation

It is important to set up structured bases for continuous improvement in every area, in order to improve the effectiveness and efficiency of the company's processes. This is a two-part process:

- improving products and services, processes and process looping through curative, corrective and preventive actions, and carrying out audits;
- determining objectives in terms of effectiveness and efficiency and criteria for evaluating whether they have been reached, and then, for all of them, set up methods, tools and techniques aimed at raising the level of quality. They will enable problems to be resolved and processes to be reworked for greater effectiveness.

In environmental and societal terms

Quality management incorporates the production tool and the product into a more responsible approach, from both an environmental and a societal viewpoint. Moreover, final users are increasingly sensitive to a company's commitment to protecting the environment and promoting the development of a responsible economy.

▸ KEYS TO SUCCESS

In technological terms

A certified production cycle and a specific internal protocol to ensure a continuous and verifiable work flow, guaranteeing both quality and effectiveness while allowing for checks and inspections in the sector at any time.

Constant experimentation and development of prototypes to create ever more advanced products in terms of effectiveness and ecology.

In digital terms

Digital transformation supports a company's quality approach. The quality function in the broad sense plays a part, assisting with methodology and monitoring the implementation of transformation projects. In this way, quality is evolving thanks to new digital tools.

With ever more advanced data analysis, incredible possibilities are emerging. Using big data can further improve the service relationship with the customer in terms of responsiveness and customisation.

In terms of skills to be mobilised, knowledge and training

Quality management refers to the quality-related activities carried out by senior management. This includes establishing a quality policy and quality objectives and determining the quality responsibilities of the various players involved. These activities are carried out through quality planning, control, assurance and improvement within the framework of a quality system. The aim is to establish strategies to improve the company's results or cut operating costs. This vital function is generally ensured by a quality director or even the managing director, in the case of smaller companies.

To certify their compliance with a quality baseline, companies go through accredited certification organisations, which conduct audits in order to verify that the practices meet a given standard.

The organisations set up indicators that lead to corrective actions carried out with a number of tools. Everything is recorded in operational documentation for which the objective is to manage its processes.

Internal and external audits ensure that the processes stay in line with the defined quality baselines.

FACT SHEET 29

PRODUCT QUALITY MANAGEMENT

Questions to ask

- It is essential to consider the organisation and its effectiveness: process reviews allow operational performance to be analysed and an improvement approach to be undertaken.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 30

PRODUCTION MANAGEMENT AND CONTROL

DESCRIPTION/DEFINITION

Production management and control cover the planning and scheduling and traceability of production operations, setting up quality control and maintenance processes, managing flows and inventory, keeping track of operators and their working time, and dashboards on all of these activities. These tasks are changing rapidly with the increasing intelligence of equipment and components (valves, pumps, engines, etc.) and the practices of self-inspection and self-diagnosis.

Main applications of these technologies:
Not limited to any particular field, production covers all industrial sectors (aeronautics, metallurgy, electronics, automotive, plastic processing, agri-food, etc.) and pertains to all types of businesses (SMEs-SMIs, large groups, VSEs).

Main technology segments concerned:
Centralised management, CAPM (computer-aided production management), MES (manufacturing execution system), MOM (manufacturing operation management, an extension of MES for a multi-factory solution covering all production-related activities, e.g. logistics, equipment quality and maintenance processes, etc.), performance dashboards (on productivity, flexibility, optimal use of equipment, environment and customer satisfaction), monitoring key indicators such as OEE (overall equipment effectiveness) on sensitive equipment (bottlenecks, special processes, etc.).

ISSUES (BENEFITS)

In economic terms

- For production:
  - better management of production flows;
  - reducing breaks in the chain;
  - lean manufacturing to cut costs.
- For logistics:
  - improving material flow (raw materials, manufactured products);
  - optimisation and reliability of delivery lead times;
  - better inventory management.
- For planning:
  - greater visibility of the activity and workshop resources;
  - facilitated coordination with the different services or clients (production, purchasing, logistics, quality, marketing, etc.);
  - managing and monitoring manufacturing reviews.
- For the process engineering department:
  - putting into perspective and capitalising on data related to manufacturing;
  - complete, centralised and shared manufacturing files (with links on documents);
  - analysing cost centres to improve productivity.
- For the quality control department:
  - reducing the rejection rate by monitoring key indicators and real-time adjustment of production;
  - compliance with internal quality processes and governmental regulations (e.g., in the pharmaceutical or aeronautical industry);
  - traceability of all elements involved in manufacturing a product, such that the relevant components can be quickly identified in the event of non-compliance.

FACT SHEET 30

PRODUCTION MANAGEMENT AND CONTROL

In technological terms

- Command and control:
  - > interconnection with external systems: remote control solutions, mobile applications and databases shared with suppliers;
  - > planning and centralised machine management;
  - > numerical control;
- Flow management:
  - > computerising order flows, in connection with ERP
  - > automating internal logistics: CAPM, ERP, PLM;
  - > external logistical interconnection: shared CPAM.
- Product traceability:
  - > batch tracking;
  - > individual part tracking: RFID chips, laser, etching;
  - > condition sensors: thermal, hygrometric, count sensors, etc.

In terms of business transformation

- Optimising use of equipment, human activities and inventory can have a profound impact on how processes are carried out. A strong commitment by management to strategic objectives such as cutting costs, quality control and continuous improvement is necessary.
- Operations tracking often requires a very precise level of detail to be relevant and involves many different players in the company who may not be accustomed to working on a shared computing tool in the workshop.
- New planning and scheduling strategies profoundly transform the production process: for example, lean manufacturing involves adjusting in real-time the quantities produced according to customer demand (requiring absolute flexibility, reliability and quality of the production lines in order to quickly manufacture small, differentiated productions).
- Increasingly mobile workstations: workers can change stations or monitor and control a machine remotely.

In environmental and societal terms

- Making workers safer: detailed tracking of operator activity and equipment maintenance procedures can provide a great deal of information, such as an overly rapid working pace, safety instructions not adhered to, inadequate training of personnel, failure to perform proper maintenance on machines, etc.
- Tracking worker activity also helps ensure compliance with local labour laws. Optimisation of storage and transport of raw materials and components (reduced CO_2 emissions).
- Reduced consumption of electricity, water, etc. by production processes thanks to optimal flow management and control.

▸ KEYS TO SUCCESS

In technological terms

- Development of HMI (human-machine interface) for control functions (information flow and ergonomics): for example, controlling production using digital tablets with simple screens requiring a minimum of clicks.
- Homogenisation and gradual integration of computerised control: MES (manufacturing execution system), PLM (product life cycle management), ERP (enterprise resource planning), SCM (supply chain management).
- Sensors provide machines with new functions (control, monitoring, predictive maintenance and autonomy).

FACT SHEET 30

PRODUCTION MANAGEMENT AND CONTROL

In digital terms

- Remote control of machines using new technical mobile applications.
- Greater control of security on the cloud.
- Optimised control and monitoring based on networks of connected sensors (Industrial Internet of Things).

In terms of skills to be mobilised, knowledge and training

- Identifying, analysing and meeting needs generated by production.
- Optimising production means in terms of cost, lead times and quality.
- Managing and identifying peripheral functions in the domain of different players.
- Developing technical and organisational connections and relationships with the players inside and outside the company.
- Managing a project, implementing and keeping track of quality-safety-environment certifications.
- Organising production management on the scale of the entire company so that industrial best practices are shared by all production sites.

Questions to ask

- Different planning parameters cannot be considered separately from performance criteria, which is why decisions have to be made. The perfect combination of parameters depends on the company's target performance level.
- Setting up an overall production management and control solution is a strategic, long-term project. It is a good idea to identify priority areas of intervention (inventory management, quality control, tracking production, etc.) in order to divide the project into manageable stages, starting with applications offering the best return on investment.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	**Mature**	Frequent	Pervasive

FACT SHEET 31

SIMULATION INFRASTRUCTURES

DESCRIPTION/DEFINITION

Simulating products and processes takes into account multi-physics phenomena applied on different spatial and temporal scales. Digital optimisation is aimed at determining the optimal settings for a large number of independent parameters (mechanics, cost, energy consumption, etc.). Simulation infrastructures have had an enormous impact in the aeronautical industry, but simulations in the broad sense affect a significant range of applications, including (but not limited to):

- meteorology;
- automotive mechanics;
- particle physics;
- electronics;
- biology;
- quantum physics.

The most common simulation methods are the following:

- digital simulation (software only);
- hybrid simulation (software and hardware);
- interactive simulation (human interaction via HMI)
- controlled simulation (human interaction via a scenario)
- instrumented simulation (human use of equipment);
- real-time simulation.

Digital simulation by finished elements is one of the most widely used methods for studying material behaviour. It is a means of virtually simulating a product in its final environment in order to meet multiple industrial priorities, such as anticipating design pitfalls, using fewer prototypes and promoting innovation.

Any digital simulation is as such an approximation of a real problem, either because it does not allow for an analytical solution or because the computer's power is limited by nature.

ISSUES (BENEFITS)

In economic terms

Simulation allows needs and constraints to be taken into account more effectively and parameters to be quickly changed at a lower cost.

Some optimisation technologies also allow savings through rational equipment use, improve the quality and lifespan of products and/or optimise production processes.

In technological terms

- Given the complexity of doing this type of calculations "by hand", digital simulations allow past, present and future phenomena to be studied. It offers an approximate presentation of the effective phenomena, so that relevant observations can be made.
- Constant technological advances in high-performance computing (HPC), the cloud and data mining techniques are expanding the scope of use for digital simulation day by day, with the implementation of a portal and tools for remote viewing to simplify access to and use of intensive computing.

In terms of business transformation

- Advances in simulation reduce production lead times and time-to-market, while also saving money. While not yet a conventional production method, it is on its way to becoming one.
- At the same time, the adaptability of simulations makes it possible to integrate them into a wide range of fields and business applications.

FACT SHEET 31

SIMULATION INFRASTRUCTURES

In environmental and societal terms

- The virtual environment created using simulation limits the number of physical prototypes that need to be produced, saving both money and energy.
- By offering a virtual test environment, simulation also reduces the number of physical or in vivo tests needed on products or equipment, allowing anomalies to be detected earlier and thus contributing to a shorter and more reliable time-to-market, often at a lower cost.

KEYS TO SUCCESS

In technological and digital terms

Adopting simulation tools requires:

- improving machine performance and interface intuitiveness: this will help popularise these solutions and promote their development in companies;
- finding a balance between human perception and modelling behaviours and environments;
- naturally integrating them into the company's computer environment;
- making the use of these tools mobile: this can apply to virtual reality, particularly in the health field.

In terms of skills to be mobilised, knowledge and training

- An action to educate companies about issues, technologies and the uses of simulation applied to their line of business, especially for digital, seems necessary.
- It seems important to expand use of digital simulation to all initial sectors: develop an instructor training programme.

Questions to ask

- Do the simulation tools adequately meet users' expectations?
- How can we technically and financially maintain the simulation tools developed?
- What is the ROI for a university or academic training course?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 35

INTEGRATION AND DIGITAL SEQUENCING OF PROCESSES

DESCRIPTION/DEFINITION

Separately and together, numerical and digital technologies are flooding the industrial environment. Digital technology is not just a reality; it has become a necessity. Companies very often see gains after introducing a new technology, but underscore compatibility problems with existing technologies, such as ERP. The goal of digital sequencing of processes is to ensure interoperability between the company's various tools and management processes in order to maximise the value added to each system. Digital sequencing is carried out using a range of tools, such as PLM (Product Life Manufacturing), EAI (Enterprise Applications Integration), EDI (Electronic Data Interchange), ERP (Enterprise Resource Planning), etc.

The diversity of professional needs, which are often highly specialised, means that computer applications are segmented. Therefore, there is no software sufficiently integrated to meet all needs, and the Department of Information Systems (DIS) has no choice but to piece together a coherent system from solutions of various origins.

Modern applications are found alongside older software, and the metaphor of the city is used to allow them to communicate with each other. It said that the information system is "urbanised", in the way that cities are urbanised to manage the combination of new and old neighbourhoods.

The fundamental challenge is to set up an architecture that enables communication and collaboration between the various entities and silos. This can only be done through a platform, i.e., a system consolidating all of the data used and produced in real time, in order to optimise the company's processes through its value chain (strategy, design, manufacturing, sales & marketing, customer service) and break down silos.

ISSUES (BENEFITS)

In economic terms

The advantages far surpass those for the information system. A platform vastly increases a company's efficiency in connection with its external ecosystem (suppliers, customers, distribution channels, etc.) by enabling the following:

- the optimisation of business line processes;
- collaboration within and between companies;
- constant connection to the customer and their experience, the key to a successful business model.

In technological terms

The platform approach ensures:

- information consistency;
- a unique urbanisation model;
- the possibility of optimising processes and working procedures by exploiting information from different sources (both within and outside the company), ultimately using artificial intelligence and big data.

In terms of business transformation

The platform helps companies develop their agility, efficiency and proximity to the market.

In environmental and societal terms

The platform is the social tool *par excellence*: it enables communication of unparalleled fluidity and in a more societal manner, allowing easier access to knowledge and know-how previously reserved for a minority, .

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INTEGRATION AND DIGITAL SEQUENCING OF PROCESSES

KEYS TO SUCCESS

In technological and digital terms

- Stacking point-to-point integrations should be regarded with circumspection.
- The platform approach is essential and must be the backbone of a company's operating system.

In terms of skills to be mobilised, knowledge and training

- Raising awareness among players in the industry about the evolution of this increasingly digital environment.
- Diagnosing digital sequencing already existing in the companies to promote the benefits of the platform approach (processes, tools, skills, etc.).
- Offering means to develop skills and supporting change management for manufacturers, parts suppliers and SMEs and MSBs.

Questions to ask

- What are my business priorities?
- What platform will best serve them?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 37

PROCESS SIMULATION SOFTWARE

DESCRIPTION/DEFINITION

Increasingly shorter time-to-market with lower related costs for complex processes or products has become a major issue. Modelling physical phenomena and simulating the impacts of systems are areas for optimisation and reducing uncertainties. Simulation software tools are aimed at improving and optimising the use of processes, maintaining the machines that support processes, and interprocess transfer and transport means.

The main applications of these technologies: a number of commercial software programs can design, optimise and track performance for most existing industrial processes in the following sectors:

- organic and mineral chemistry from heavy chemicals to fine chemicals;
- petrochemicals and carbo-chemicals;
- coal liquefaction / gasification
- agri-food;
- mineral processing;
- biotechnology;
- foundry;
- plastic processing;

Main technological segments concerned: software for the simulation of production and logistical systems, process optimisation, PSO (process simulation and optimisation), CAM (computer-aided manufacturing), manufacturing process simulation.

ISSUES (BENEFITS)

In economic terms

- Process simulation allows manufacturers to both improve the efficiency and cost-effectiveness of an existing process and simulate a new production unit.
- Earliest possible detection (before testing the prototypes) of design errors and problematic effects of coupling.
- Optimising the cost of preventive maintenance by accurately estimating wear and the replacement of production equipment.
- Reducing cost and time spent on qualification tests.

In technological terms

- Taking constraints related to the operating environment into account from the design phase.
- Topological optimisation and better perspective on the feasibility of new complex forms.
- Lighter structures, whether for economic or ecological reasons, has become an everyday challenge for designers.
- Improving the quality and traceability of finished products.

In terms of business transformation

- Radical transformation of practices in design offices that can virtually test the product in future operational conditions.
- Educating operators and improving learning on a realistic virtual base.

FACT SHEET 37

PROCESS SIMULATION SOFTWARE

In environmental and societal terms

- Reducing waste thanks to virtual prototyping.
- An increasingly developed role in product life cycle management.

KEYS TO SUCCESS

In technological terms

- There is room for improvement in these software solutions for them to be both accurate and easy to use in order to adapt to various additive manufacturing processes, which are still evolving and in great need of solutions.
- Taking into account multi-physics phenomena applied on different spatial and temporal scales.
- Determining the optimal settings for a large number of independent parameters (mechanics, cost, energy consumption, etc.)

In digital terms

- Ensuring access to sufficient computing resources.
- Developing tools and platforms to enable intensive computing.
- Developing new human/machine interfaces to improve the ergonomics and simplicity of simulation software solutions.

In terms of skills to be mobilised, knowledge and training

- Need for in-depth knowledge of the physics of the phenomena in order to model the behaviours applied on different scales, and to correctly interpret the results.
- Using the tools remains complex and is often limited to specialists in digital simulation.
- Training designers in managing these tools is long.
- Difficulty in experimenting to validate all aspects of the multi-physics model.

Questions to ask

- Is process simulation software going to become a pay-per-use offer?
- What offers on the market are developed enough to match companies' needs?
- How can we use simulation within the scope of non-destructive testing of operations?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 40

DIGITAL MODEL OF THE FACTORY

▸ DESCRIPTION/DEFINITION

The digital model is the cornerstone of the factory of the future. A digital model enables virtual testing of everything that happens in the factory (introduction of new machines or processes, change in product characteristics, increase in volume of customer orders, impact of a change in supplier, etc.) in order to better anticipate all of the impacts before the real entry into production. The notion of the digital twin, representing both the factory and its environment, is recent and consists of connecting this model to sensors installed on the industrial equipment in order to monitor production in real time. It is a virtual replica of the factory used to detect problems and test and simulate scenarios on its "real-world" physical counterpart.

Main applications of these technologies: all players invested in an industry 4.0 approach are concerned by the concept of a digital twin of their production sites.

Main technological segments concerned: virtual engineering and data fusion (holistic approach), flow simulation (products, tools and equipment, measurement and inspection instruments, consumables), 3D scanning, scene scanning, scanning large objects using drone, space control and monitoring using land robot and drone.

▸ ISSUES (BENEFITS)

In economic terms

- Early discovery of deficiencies at the virtual level: operators simulate the results before the physical processes and products are developed.
- Assessing a system's current and future abilities throughout its life cycle.
- Optimising the operation, manufacturing and inspection of equipment or building(s).
- Continuous improvement of designs and models thanks to data collected.
- Virtual simulation of scenarios (changing locations of machines, adapting the line to produce a new range of products) which reduces downtime of production lines or time required to ramp up production of a new product.

In technological terms

- Recovering digital models from the design-build phase (DOE, design of experiments) to optimise operational maintenance of the site or equipment.
- Querying and maintaining the digital model in order to anticipate and budget / plan for work and adaptations needed to keep the factory operating smoothly throughout its life cycle.
- Integration of documentation (technical sheets on equipment, materials, etc.).
- Simulating redistributions of space to accommodate different uses.

In terms of business transformation

- Collaborative work to build and update the digital model: faster and more efficient project review in view of new investments or adaptation of the site.
- Modelling and simulation throughout an infrastructure's life cycle, connecting players, co-producing and sharing data for intelligent systems, connected objects, mobile interfaces and applications, and virtualisation are areas shaping economic new models.

FACT SHEET 40

DIGITAL MODEL OF THE FACTORY

In environmental and societal terms

- More fluid transmission of information and better understanding of the working environment at all levels of the factory's management chain.
- Better understanding of energy consumption and decision-making in favour of a sustainable factory.

KEYS TO SUCCESS

In technological terms

- Machine learning, artificial intelligence, advanced simulations based on real-world data and 3D modelling considerably expand the benefits of digital twins of factories, especially in the industries with high-added-value or critical assets.

In digital terms

- Appropriation of digital factory software and involvement of all different departments in understanding and interpreting data.

In terms of skills to be mobilised, knowledge and training

- Digital transformation of construction is leading to new modes of designing, building, operating and experiencing works and infrastructures based around the shared use of digital models.
- Greater awareness of "multi-use" or "multi-scale" (from the entire network of factories and the supply chain to a single production line tool) aspects of the digital model.

Questions to ask

- Time frame for deployment in manufacturing companies: the agency ABI Research estimates that 54% of players will have implemented this technology by 2026 for predictive maintenance applications.
- Popularise the digital model in PMEs and MSBs in the building and public works sector and with clients.

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

FACT SHEET 48

OPTIMISATION OF MAINTENANCE, PREDICTIVE MAINTENANCE

DESCRIPTION/DEFINITION

The advent of the Internet of Things and big data now gives us real-time access to data on product behaviour and usage (HUMS, Health and Usage Monitoring System).

This approach consists of collecting and analysing a device's data in order to optimise its maintenance (dynamic reconfiguration of inspection or part replacement schedules). Predictive maintenance goes a step further than curative maintenance, which is making a repair once a failure has occurred, or preventive maintenance, which involves scheduling maintenance tasks based on event statistics.

- The data collected must be relevant and in accordance with the basic characteristics of big data, the "5 Vs":
  - > **Volume:** a certain amount of data needs to be amassed in order to be able to deduce results from it;
  - > **Velocity:** it is also imperative to collect and process these data in real time;
  - > **Variety:** the type of data collected can vary widely (texts, images, etc.);
  - > **Veracity:** the data must also be reliable;
  - > **Value:** with the era of big data will come an ever greater quantity of data. It is therefore important to be able to focus on the data with true value.

Predictive maintenance is becoming a key tool for managing product performance, productive equipment and organisations, providing feedback on how to redesign or redefine them.

ISSUES (BENEFITS)

In economic terms

- Facilitated ranking of maintenance operations thanks to predictive analysis and solutions from software publishers.
- Lower maintenance costs enabled by scheduling maintenance tasks during off-peak hours.
- Anticipating a failure, managing machine downtime, increasing machine lifespan, reducing spare parts inventory.
- A ROI of between two and three years according to the manufacturers queried.

In technological terms

- Using the Internet of Things and the latest real-time algorithmic advances provides knowledge of the exact conditions of use of the products. This has a direct impact on the maintenance, design and choice of manufacturing processes.

In terms of business transformation

- Allows a product's quality to be fully managed over its entire lifespan, thereby contributing to an excellent reputation.

In environmental and societal terms

- Predictive maintenance extends the lifespan of products, making it a key CSR priority.

FACT SHEET 48

OPTIMISATION OF MAINTENANCE, PREDICTIVE MAINTENANCE

KEYS TO SUCCESS

In technological and digital terms

- Having the mechatronic and IT skills and means required to set up predictive maintenance.
- Managing significant change in the vision of the product. Real usage is more important than expected usage.

In terms of skills to be mobilised, knowledge and training

The culmination of integrating big data for predictive maintenance comes after thorough reflection and a complex process. It is a matter of inputting the mechanisms occurring at the time of failures, thereby establishing a "signature" for the problem. This requires close collaboration between the experts in the field and the data experts.

- The data scientists tasked with developing failure prediction algorithms rely on the knowledge of engineers in the field and maintenance technicians:
  - > indeed, a data scientist on their own would have a hard time producing convincing results without operators on site to steer them in the exploratory phases;
- training project coordinators to communicate with the data scientists.

Questions to ask

- It is important not to be overly ambitious at first. Is our maintenance already at an acceptable level?
- To be able to set up predictive maintenance, all machines must first be connected to a data collection system, which takes time. The difficulty lies in the fact that the system is not always able to understand the language of different machines.

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	Mature	Frequent	Pervasive

FACT SHEET X07

LEAN TOOLS AND APPROACHES

DESCRIPTION/DEFINITION

Lean principles are a lever for organisational and managerial innovation. Lean manufacturing, modelled by MIT in the 1980s, emerged as an incremental lever for innovation by eliminating all forms of waste and surplus and applying lean tools within the company's processes in order to optimise them in terms of lead time, quality and cost. The benefits of lean practices are generally lower transit time for the product or service, better quality, better cost control, and faster response time. Lean manufacturing, which had difficulty securing long-term results, evolved into lean management, a lever for organisational and managerial innovation which changed the perspective on how to achieve performance. Performance became something activated by innovation that broke with the conventional managerial model. The lean system deployed is based more on creating and developing collective intelligence: team work, team responsibility and autonomy with a shared vision and a spirit of entrepreneurship, allowing for greater potential that lasts over time.

Lean management is key asset in creating the factory of the future:

- by promoting the implementation of process technologies selected with reason (e.g., robotisation/automation, digital visual management);
- by maximising the achieved added value (e.g., development of new products/services with a competitive time to market);
- by supporting the personnel and teams in the company's perpetual transformation.

Main applications of these technologies:
Lean management aims for complete customer satisfaction by continuously optimising the company's offer. This makes it relevant for every type of activity.

- A historic dynamic in industry: lean manufacturing in the automotive sector, and then every type of industrial activity. Moreover, lean approaches for each sector are becoming common in the automotive and aeronautical industries.
- They are also growing in other sectors such as finance, mass distribution, medical, building and public works, craft and guild trades, real estate, agriculture, military, transport, administration, etc..
- From VSEs to major groups, from per-unit to mass production, from manufacturing to service, from the sales department to the logistics department, from make-to-order to make-to-stock: every type of activity encountered now has a benchmark in lean practices.

Main technological segments concerned: visual management, management routines, problem resolution, versatility, instructor training, lean tools (VSM, 5S, A3, etc.).

ISSUES (BENEFITS)

In economic terms

- Creates overall efficiency for the company.
- Supports the company's competitiveness and growth: capturing new markets, improving margins, operational excellence.
- Efficiency of the extended enterprise in the case of a lean supply chain.

In technological and methodological terms

- Visual management: warning system close to where decisions can be taken.
- Improved ability of the company to handle its problems (quality, safety, costs, etc.).

In environmental and societal terms

- Defining a vision, values, a strategy and objectives that are simple, consistent and shared by all.
- Improving working conditions.

FACT SHEET X07

LEAN TOOLS AND APPROACHES

- Eco-efficiency.
- Encouraging responsibility and autonomy.
- More cooperative management in order to involve everyone, striving for a leader-coach model.
- Improving the company's overall operation/improving the company's image, attractiveness to customers and talents.

▸ KEYS TO SUCCESS

In terms of technology, methodology and skills to be mobilised

- Translating the strategy into operational areas that the lean approach will support.
- Coordinating the approach and active involvement of management.
- Designating a change agent recognised for their soft skills, e.g., leadership, coordination and educational skills. Knowledge of lean hard skills is also an asset.
- Setting up a high-performance communication unit: a system of managerial routines allowing for bi-directional communication, using the appropriate organisation (matrix, hierarchical, process-based, etc.).
- Setting up a high-performance problem resolution system: defining decision levels and fast triggers for transfer to the next level up if resolution of a PDCA-type problem is blocked.
- Support from external experts in advising and training as needed, and the company benchmark (through Gemba Walk, industrial tours, change agent in shared time, etc.).
- Transmission of the change agent's lean skills to the managers to ensure the robustness of the approach over time.

Questions to ask

- The delay in deploying lean management in France.
- Lean manufacturing and the relationship to occupational health.
- Emerging organisational innovation models: after lean management, “learning enterprise”?
- Lean management and the extended enterprise.
- The future of lean in the era of mass customisation and digital technologies.

▸ MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	**Frequent**	Pervasive

FACT SHEET 18

DIGITISATION OF THE CUSTOMER RELATIONSHIP

DESCRIPTION/DEFINITION

Digital technology is transforming the relationship between companies and their customers. This omnipresent, multi-channel and increasingly real-time relationship is a key source of added value. Customer relations are becoming both richer and more complex, and digitising them must offer a better response to changing habits (computerisation of the buying process, sharing information on social media, etc.), be a source of added value (developing services, etc.) and allow for differentiation on the market. To support and better understand customer relations, digitisation requires not only collecting information, but especially providing information throughout the entire process, which combines physical and virtual contact.

Digitisation offers a host of opportunities for better understanding and interacting with customers, i.e.,

- varied digital tools for promoting products and helping bring new services to light while also aiming to develop more direct and personalised relationships with customers: interactive website, social media, forums, blogs, etc. By sharing one's opinions and commitment to the product and posting one's purchases online, the customer becomes an integral part of the production line.
- Enhancing customer knowledge by integrating the log of all interactions, both online (interactive tools, connected objects, etc.) and off-line (CRM, cloud, marketing automation, etc.), and making them accessible to all of the company's departments.

The link between companies and their customers is also radically changing:

- Becoming a relationship-oriented brand means ensuring a maximum level of listening and attentiveness, service and responsiveness on all channels of interaction, while also prioritising close relationships.
- To adapt communication to these expectations, companies are changing their internal organisation, including the qualification of business lines and knowledge distribution.

However, the digitisation of customer relations faces one major hurdle, which is convincing all business lines that they must constantly update and pool their information in real time. This approach involves radically rethinking conventional organisational models.

ISSUES (BENEFITS)

In economic terms

- Increasing the company's visibility on the market and thus access to new customers.
- Gaining greater credibility with customers, thereby strengthening customer loyalty to the company (lower customer churn).

In technological terms

- Turning big data into smart data by collecting large amounts of information on the customer life cycle, by making the data meaningful in order to use them for strategic purposes and switching from a rationale of volume to a rationale of targeting (personalisation).
- Integrating CRM (customer relations management) software or a data management platform (DMP) in order to:
  - > manage all of the information in a structured, centralised and harmonised way;
  - > structure a catalogue of products and services;
  - > organise the different business lines and expand the database with each new interaction with the customer.
- Synchronising the customer relations management software with all of the digital channels.
- Integrating predictive analysis systems to allow buying behaviours to be anticipated (marketing automation).
- Using artificial intelligence to generate targeted message (chats, chatbots, etc.).

FACT SHEET 18

DIGITISATION OF THE CUSTOMER RELATIONSHIP

In terms of business transformation

- Integrating digital culture into the company's departments:
  - > break down the conventional segmentation between departments;
  - > redesign all of their management methods and processes;
  - > pool information from different business lines.
- Developing the ability to utilise the customer's knowledge, communicate the values embodied by their brands, and offer an enhanced customer experience.
- Focusing on customer management processes at the different stages in the customer life cycle, from purchase to loyalty.

In environmental and societal terms

- Strengthening the connections and areas of communication between the company, its internal structure and its external ecosystem.

KEYS TO SUCCESS

In technological and digital terms

- Protecting the personal data and information of customers/consumers.
- Accepting the customer's role in the company: working together.
- Integrating the new professions relating to big data: data scientists, data analytics, etc.

In terms of skills to be mobilised, knowledge and training

- Motivating and uniting all of the company's departments and business lines around a single vision based on customer service.
- Dedicating more time to listening to customers-consumers and the feedback they provide.
- Developing employees' digital skills (collecting, processing, and analysing data, IA, etc.) and customer relations skills.

Questions to ask

- How can we create a profoundly digital and customer relations-based culture in the company, between the different departments and areas of expertise, to help strengthen a closer relationship with the company's customers and external ecosystem?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 19

DIGITISATION OF THE SUPPLY CHAIN

▸ DESCRIPTION/DEFINITION

There are many advantages to digitising the supply chain, the primary one being breaking down divisions between the different departments within the company, making it easier to create a common plan and offer customers new experiences. All of the players (supply, production, logistics, marketing, finance) will also have greater visibility of the overall supply chain, allowing them to optimise their processes, cut costs, manage inventories, serve an omnichannel approach and ultimately improve margins and increase market shares. Digitisation must allow the supply chain to be orchestrated in real time, or at least aim for this unit of measuring procurement time.

This is of course a digital revolution; digital transformation is first and foremost cultural. Beyond the tools that are inevitably making their way into factories, warehouses and transport providers' systems, a successful technological transition seems to involve co-managed projects in which all concerned players take part.

Experts describe a collaborative working environment as one of the keys to success. This allows each party to provide a cornerstone by contributing information in real time, with better visibility and greater security, which is what teams in place are asking for. Thus, technological evolution involves increasing the contact and connection between the company and its stakeholders (transport providers, suppliers, etc.), in the aim of standardising communication to make it simpler, easy to use, and more relevant in the day-to-day.

The approach also involves taking advantage of the massive amounts of data collected by the tools of various stakeholders (transportation companies, customs departments, etc.) by recovering and analysing these data, which provide an excellent basis for upgrading logistical and transport procedures. The idea is to create a system in which the various players fill in the entire value chain with the available data, allowing the right investment and planning decisions to be made for the entire logistic supply chain.

Moreover, with the complexity of international trade regulations, computerised solutions provide companies with better traceability, safer entries and a simplified means of communication with sales management platforms.

The supply chain planning process can be summed up in three steps:

- Step 1 is to analyse the past in order to understand the present and attempt to foresee the future by deducing relevant demand scenarios.
- Step 2 will be to plan the human and physical resources in order to best meet the needs of the selected demand scenarios.
- Step 3 will apply these plans in real time, providing information for revising and/or correcting the demand models.

▸ ISSUES (BENEFITS)

In economic terms

- Improving the company's results by closing the gap between the plans that have been made, based on the company's strategy, and their implementation.
- Determining the best possible sales potentials, eliminating shortages, optimising and planning logistics flows and anticipating human activity.

In technological terms

- Simulating multiple scenarios in order to anticipate demand and plan the various available resources in an optimal and robust manner.
- Working on extraordinary amounts of data, managing exogenous data (weather, social media trends, etc.), and measuring the impact of each product characteristic on its sales curve (price, composition, level of exposure, etc.).

FACT SHEET 19

DIGITISATION OF THE SUPPLY CHAIN

In terms of business transformation

- Digitisation breaks down the barriers between different players in a company and facilitates interaction.
- Digitisation also stimulates the automation of tasks and optimisation of document flow, ultimately accelerating overall logistics flow. However, digitisation is not limited to the computerisation and automation of document processes.
- Companies that set up information systems capable of collecting these data, and processing them to make them exploitable in the form of dashboards, will acquire a powerful competitive edge in terms of business intelligence.

In environmental and societal terms

The combination of business line expertise and new-generation optimisation and forecasting tools improves overall performance by facilitating anticipation and decision-making, as well as by enabling the management of specific cases and exceptions to the general logistics framework. Thus it has a real socio-environmental impact.

► KEYS TO SUCCESS

In technological terms

- Solutions allowing data to be quickly and easily centralised by regularly updating the associated use cases.
- A company content management system.
- An operational and transactional building block bringing together all data from all silos in order to have a single consolidated view, as well as the ability to perform actions serving existing and future applications.
- An integrated planning platform allowing the company's strategic goals to be aligned and closing the gap between planning decisions and operations.

In digital terms

- Mathematical modelling and optimisation (using operations research tools) of the entire supply chain.
- Compiling and analysing general data generated by products, associated with information on customers and aggregate data stored on systems that can be used for support and operations, to create new services, optimise competitiveness and boost customer satisfaction.

FACT SHEET 19

DIGITISATION OF THE SUPPLY CHAIN

In terms of skills to be mobilised, knowledge and training

- Teams of specialists in data analysis, statistical modelling and operations research optimisation.
- Profiles of chief data officers or master data managers and data scientists to organise better governance and exploitation of their data.
  - The chief data officer (CDO) reconciles the data in the baseline with sales and supplier data, while also including data pertaining to customers.
  - The CDO strives to make data interoperable for all of the brand's services and reveals hidden opportunities to each party.
  - The CDO ensures that data are better exploited so that the best possible decisions can be taken in line with the company strategy.
- Integrating adequate talents to modernise traditional roles while preserving the experience of business line teams.

Questions to ask

- What are the use cases?
- What high-added-value experiments on a reasonable scale can I set up?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 26

END-OF-LIFE OF THE PRODUCT

DESCRIPTION/DEFINITION

Every product follows a life cycle, from the extraction of its raw materials to production and ultimately its destruction or recycling. There are impacts on the environment (depletion of resources, air/water/soil pollution, greenhouse gas emissions, etc.) at each of these steps. Managing product end-of-life involves planning and carrying out operations to withdraw the product from the market with least possible environmental impact, at optimal cost. This may include disassembly, recycling (waste, raw materials, etc.) or deconstruction.

The linear model of production and consumption (extract, produce, consume, throw away) has significant environmental impacts. Extending a product's lifespan is one way of reducing its impact on the environment, as is effectively managing its end-of-life.

Recycling, in particular, is both a means of waste disposal and a method of resource production. In the ranking of waste processing modes, it comes in third position after prevention and reuse.

ISSUES (BENEFITS)

In economic terms

Planning for product end-of-life in the design phase can be a clear competitive edge.
Setting up recycling channels can lead to significant savings in producing raw materials, especially when these materials are scarce.
A product's true production cost must take into account all direct and indirect charges at every stage in its life cycle. This is the total cost of ownership or life cycle cost.

In technological terms

Products must be designed in such a way as to be easily dismantled for reuse, recycling, or the possibility of being turned into usable energy.

In environmental and societal terms

Managing product end-of-life is one of the fundamental building blocks of the circular economy.

There are two types of recycling:

- Closed-loop recycling
  Using end-of-life products for the same purpose, without functional loss of material. E.g. recycling a PET bottle into a PET bottle, recycling glass packaging into glass packaging, recycling asphalt into new asphalt, etc.

- Open-loop recycling
  Using the recycled material for a different purpose, as a substitute for primary raw material: recycling a PET bottle into fleece fibre, recycling paper into insulation, etc.

In any case, the goal is to take fewer raw materials from nature, as certain materials are becoming increasingly scarce.

KEYS TO SUCCESS

In technological terms

Within the process of product end-of-life, each stage in the cycle can have a variable impact on the different steps, from waste collection to production of goods. Ecodesign addresses the following parameters:

- incorporating secondary (recycled) raw materials (SRM), design with a view to disassembly or recycling, calculating the recyclability rate;

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END-OF-LIFE OF THE PRODUCT

- collection, determining the level of mobilisation of waste stocks and used products for recycling;
- dismantling (disassembly and pollution control), sorting (identifying, extracting and/or separating materials) and preparing (shredding, grinding, etc.) the resulting waste and materials, which increases and regulates flows. At this stage, the issue is to optimise the quality of SRM while reducing the amount of non-recycled ultimate waste;
- processing and implementing materials from waste, helping to incorporate more SRMs in existing or new fields of application.

In digital terms

New digital tools allow waste collection and processing to be digitised, optimising management and traceability. It is also possible to bring waste producers into direct contact with the players that assist with product end-of-life.

In terms of skills to be mobilised, knowledge and training

The company must develop its skills in various areas:

- knowing the local and regional industrial fabric to define a possible circular economy partnership (I use other parties' waste products and make my waste products available for use);
- knowing the processes that can be used to facilitate dismantling or disassembly for sorting/recycling purposes;
- developing know-how regarding materials and possible ways of processing them after their use in a product;
- knowledge of existing re-processing channels.

Questions to ask

- Consideration of product end-of-life from the design phase must lead the company to study the established production and procurement schemes in order to develop a circular economy based on recycling waste.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 2

ADAPTATION OF ENERGY CONSUMPTION

DESCRIPTION / DEFINITION

Industry is seeing a drop in its energy consumption, resulting from the large-scale action taken to improve their energy performance in recent years. While some offerings focus entirely on energy efficiency (such as energy management systems and energy audits), current investments tend to complement other investments made for other reasons (such as the renewal or maintenance of equipment, upgrading to standards, etc.) and are thus one-off actions forming part of a specific action plan.
On the other hand, with the carbon market and the fight against climate change gaining more ground every day, reducing greenhouse gas emissions and energy efficiency seem to be vectors for innovation. Today, gas and electricity are the energies most consumed (2/3 of the total for the two of them).

The five sectors that consume the most energy in France are as follows (85% of total consumption):
- the paper and cardboard industry;
- the agri-food industry;
- the rubber, plastics and other non-metallic mineral products industry;
- metallurgy;
- the chemical industry.

Among the uses of electricity, motors consume 2/3 of all electricity (ventilation, compressed air, pumping, etc.). The main emerging technologies are:
- energy monitoring-sensors;
- software algorithms for analysing energy performance;
- software algorithms based on artificial intelligence for regulating the operation of energy systems;
- sensors and software for connecting ageing and/or digitally isolated machines;
- storage and energy systems – *Power to gas, power to pressure head*, etc.

ISSUES (BENEFITS)

In economic terms

- Reduction of energy procurement costs.
- Savings related to reduced loads and wasted energy.
- Increased chances of attracting investors / access to finance.

In technological terms

- Increased autonomy of processes consuming fossil fuels.
- Gain through the intelligent use of an energy mix, including renewables, thanks to integrated smart grids coupled with efficient storage technologies.
- Recovery of unavoidable energy by Organic Ranking Cycle (ORC)-type systems.
- Automatic detection and prevention of leaks of fluid and electricity.
- Gain by energy recovery (heat, kinetics, etc.) and storage or re-injection into the network.
- Optimising equipment sizing and upstream energy requirements (for example, by avoiding the over-sizing of energy consuming systems, adapting the energy need to the useful energy demand).
- Thinking in systems rather than in components.

FACT SHEET 2

ADAPTATION OF ENERGY CONSUMPTION

In digital terms

- Developing algorithms to monitor the behaviour of processes and the comparative analysis of data between sites (big data approach).
- Total process connectivity in the company's IT network for remote monitoring and intervention purposes and to build an energy profile.
- Compatibility of operation of local smart grids with the central management of the company, to consolidate all energy consumption and production.
- Measurement of energy performance and management and real-time control of energy.

In terms of business transformation

- Improving the competitiveness of the company.

In environmental and societal terms

- Improving the corporate image - fighting climate change, reducing the carbon footprint.

KEYS TO SUCCESS

At the technological level

- More efficient and less energy-consuming digital technologies.
- Integrate intelligence into distribution networks to coordinate supply-demand balances in real time.
- Create autonomous systems for collecting and analysing big data.

In digital terms

- Use software dedicated to measuring the energy consumed, optimise consumption, manage alerts.
- Use the big data base to set up digital tools for regulating and anticipating energy consumption based on *machine learning* and *deep learning*.

In terms of skills to be mobilised, knowledge and training

- Raise employee awareness at every level.
- Analytical Capabilities - big data.
- Adapt the energy efficiency approach to the energy source in question.

The questions to ask

- Consolidation of a carbon market and taxation of emissions by industry.
- Development of the EnR (renewable energies) offer to consider investment in a storage solution.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	**Frequent**	Pervasive

FACT SHEET 20

ECODESIGN

DESCRIPTION / DEFINITION

A creative approach and a source of innovation and differentiation, ecodesign is a positive approach to environmental issues and a lever for creating value. It is both a preventative approach to environmental problems and a product-centric approach that can be applied in every sector of the economy. It is currently implemented to varying degrees and with a wide variety of tools in a very wide range of sectors such as the electronics, automotive and aerospace industries, equipment products and most fast-moving consumer goods.

It is characterised by a global vision of a product's environmental impacts: it is a multi-stage approach (taking into account the various stages in a product's life cycle) and multi-criteria (taking into account the product's consumption of matter and energy, discharge of waste into the environment, effects on climate and biodiversity).

Ecodesign is coordinated by a company or public body, but it involves a large number of stakeholders all along the product value chain and even beyond, including consumers or users, and even waste processors and recyclers. Its value lies in examining the relationship between design choices for a product and the material and energy flows that result throughout its life cycle.

The process is broken down into:

- a multi-criteria environmental assessment of the product's life cycle;
- identification of the main environmental impacts relevant to the study in question;
- identification of levers for taking technical and/or organisational action, to improve a product with higher environmental performance, while maintaining the functions, services and performance characteristics of the product. The approach addresses business, innovation, regulation and communication issues.

Ecodesign is used by major corporations as well as SMEs and VSEs, professional organisations and engineering centres, which apply it alone or with the help of specialised consultants. Its use is closely related to environmental assessments of the life cycle analysis type. It requires a good understanding of the concepts. However, it is possible to use ecodesign without conducting a life cycle analysis study, by using input-output analysis approaches or material or energy flow analyses. Ecodesign is also at the base of various public and private tools, such as eco-labels and greener purchasing policies.

Ecodesign is one of the environmental management tools (ISO 14000). It is guided by a normative standard, ISO 14062 (ecodesign in theory and practice) which provides guidelines to implementing the approach. Environmental assessment, in the sense of life cycle analysis, is a strict standard (ISO 14040), although the calculation methods, allocation rules and basic data are still the subject of scientific and technical debate.

Regulations are levers for changing products, their uses and even their end-of-life treatment. For example, regulations on the energy efficiency of products and equipment have been established at European level under two framework directives. The first relates to the ecodesign of products and uses regulations to define minimum performance requirements for products placed on the market, and thus to ban those which are least efficient. The second relates to the energy labelling of products. Regulations on Extended Producer Responsibility (EPR), or on restrictions on the use of hazardous substances (REACH or ROHS), are part of circular economy approaches.

FACT SHEET 20

ECODESIGN

▸ ISSUES (BENEFITS)

In economic terms

- Ecodesign is above all an arbitration process between sometimes contradictory objectives with a vision of every stage in the product's life cycle, including quality, costs, lead times, safety and environmental issues.
- The first steps in ecodesign are often easy and inexpensive to implement. They can coincide with common-sense options to reduce costs: material savings (by lightening) or energy consumption, optimisation of the supply chain (truck filling rate, cold chain), less waste to treat.
- Ecodesign identifies new areas of value creation for its products and offers a triple benefit to company directors:
  - (assets) by increasing the value of the company (earnings, corporate and brand image);
  - (customers) by responding more closely to their expectations and offering innovative products;
  - (ethical value) by integrating the notions of corporate social responsibility.
- Research with customers and suppliers for common solutions to address the waste disposal issues in the sector is a source of innovation which benefits the circular economy. New solutions are emerging, as well as new business models.
- Ecodesign is part of a process to reduce the consumption of materials or energy (with direct economic gains) produced in its use, but also in manufacturing, supply chain or end-of-life phases.
- Ecodesign can lead to proposals for services or product service systems that modify organisations, stakeholders and value chains.

In technological terms

- Regulatory monitoring and anticipating restrictions on the use of certain substances stimulates an alternative programme through the research and development of new materials (recycled, bio-based) or new technologies (less energy-intensive, easier to maintain, easier to dismantle, etc.).
- The search for reductions in the environmental impact of the manufacturing phase can, for example, lead to the pooling of production lines and the use of crushed or recycled products, thus bringing productivity gains, etc.

In terms of business transformation

Ecodesign mobilises the involvement of many activities within the company including the design, marketing, purchasing, production, quality, and sustainable development departments. It forms part of the corporate strategy by involving all of the stakeholders, from strategic thinking to solutions and operational implications. The interesting and motivating nature of ecodesign boosts synergies between the teams within the company. Close cooperation with customers, suppliers and service providers helps to identify expectations, trends and available techniques.

In environmental and societal terms

- Reduction of the environmental impacts of products throughout their life cycle: extraction of raw materials, production, distribution, use and end-of-life.
- It contributes environmental gains ranging from the preservation of resources and biodiversity, the prevention of pollution and nuisance, climate balance and land usage.
- Lever for the development of the circular economy.

FACT SHEET 20

ECODESIGN

KEYS TO SUCCESS

At the technological level

- Go through the main phases of a technological project justified by the modification of an existing system, imagine and represent the principle of a technical solution based on a creative approach.
- Define all or part of a mechanism and one or more associated parts and anticipate their behaviour by simulation.
- Discover by experimentation the principles of the main processes of materials processing, produce a part by a rapid prototyping process and validate its definition by its integration in a mechanism.
- Develop low-energy solutions.
- Offer more robust products for more intense or longer uses, with architectures capable of integrating modularity or even the recovery of components or materials at the end of their service life.

In digital terms

- Develop digital tools that are more functional and faster and that consume fewer resources; develop connected objects that are more robust, repairable and generate less waste.

In terms of skills to be mobilised, knowledge and training

The skills required are those of design office staff trained in ecodesign methodology:

- ecodesigner or ecodesign engineer: for the time being, these professions are not yet widespread. But there are some in every sector of activity. Their tasks: to carry out impact studies, analyse the human and environmental characteristics of the region, define the choice of materials and technology and develop the workshop drawings for the product;
- Ecodesigning is a job that requires a certain versatility and that we should see emerge in the coming years. Proof of this can be seen with the new training courses that are emerging;
- ecodesigners may be closely linked to the HSE services of a company and may have had relatively varied and open initial training: scientific training of the engineering type, training in the life sciences or geosciences.

The questions to ask

- Make sure all the risks and opportunities related to the design of a product are taken into account.
- Question your company's maturity with respect to ecodesign approaches, environmental assessments, positioning with respect to existing regulations or labels.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

USEFUL LINKS

Contributors: Arts et Métiers (Nicolas Perry / I2M)

FACT SHEET 21

CIRCULAR ECONOMY

DESCRIPTION / DEFINITION

The global context of growing populations and decreasing resources and raw materials makes it necessary to think about the transition from a linear economy to a circular economy. Land-use planning must help by limiting silo approaches and by acting in an integrated manner so that all the resources in a region are mobilised with a single objective: to make the region and the towns within it low-carbon and resolutely circular.

Against this background, a large number of business models stand out for their qualities in the management of resources and are positioned as vectors for innovation and competitiveness factors. The circular economy must promote emerging initiatives in each region to advance in a society that has less impact and open the way to the creation of value that is not based on the consumption of finite resources.

In France, the circular economy is based on seven main lines of action:

(1) ecodesign & environmental management;
(2) the exchange of secondary resources between companies (ecology or industrial symbiosis);
(3) the product-service system that generates little waste, and more broadly innovative business models;
(4) reuse;
(5) repair;
(6) repurposing;
(7) recycling.

The factory is a key factor in the environmental issues of our time. Thanks to the circular economy, it makes a significant contribution to resolving these problems and fits harmoniously into the community by optimising the use of common resources or by creating energy.

ISSUES (BENEFITS)

In economic terms

For businesses, the circular economy is undeniably a lever for competitiveness and an opportunity for the development of new markets, in particular due to the difficulties linked to the procurement of raw materials. The transition to a circular economy can be used to:

- reduce costs, reuse and remanufacturing being important drivers of the circular economy.
- benefit from a sustainable supply by reducing the impact of the supply of raw materials and by making it possible to replace them with renewable or recycled raw materials.
- generate value: the transition from possession to use is also an opportunity. It offers the possibility of strengthening customer relationships and building loyalty.
- anticipate future regulatory or economic constraints: the issues involved, both economic and ecological in nature, will not fail to attract the attention of regulators, and companies have an interest in anticipating them.
- symbolise environmental excellence: corporate and brand image risks are sufficiently important to justify the transition.

In technological terms

An open model accelerates this nascent transformation and enhances the most interesting loops by making them readable and intelligible. A model of this kind is based on:

- the opening of data on the life cycle of products and services;
- the accessibility of codes and plans for products and services;
- documentation on practices and experiences;
- the publication of results.

FACT SHEET 21

CIRCULAR ECONOMY

In terms of business transformation

Ultimately, the goal is to create networks between companies to pool what can be shared in terms of human resources, equipment and mobility, and to study flows so that one company's waste becomes another company's resource. Manufacturers are already creating sustainable business models using remanufacturing, recycling and, more recently, the emergence of collaborative practices. But a more global view of the fight against waste shows that the circular economy still has great potential for development. In addition to sharing and recycling, other approaches related to products as a service, to extending product service lives and to the circular supply chain will transform the industry's business models. The challenge is to extend their activities beyond the world of low-margin manufacturing.

In environmental and societal terms

Through links between stakeholders in the value chain, symbiosis is designed to optimise the management of resources within each region. Their success depends on the participants' commitment, which is strongly influenced by the results and their potential benefits, and measuring both.

For businesses and the regions in which they are located, quantifying gains helps with decision-making. Performance measurement is essential, both for accountability to backers and to discern the best way forward to ensure the sustainability of each symbiosis. However, experience shows that this exercise has several obstacles: the variety of stakeholders and their differing interests, issues of confidentiality, lack of reliable data and common indicators, undeveloped calculation methods, etc.

KEYS TO SUCCESS

At the technological level

- Sharing good technological practices between stakeholders in the same sector.
- The development of shared platforms between players to promote inter-company cooperation.

In digital terms

- The propagation of a common digital culture based on the synchronisation of the issues at stake and the ambitions of companies in the same sector in order to establish a genuine sectorial strategy.

In terms of skills to be mobilised, knowledge and training

- Develop environmental awareness and a genuine common strategy with all of the employees and stakeholders in the activity in question.

The questions to ask

- What means need to be mobilised in order to instil and propagate common aims around circular economy issues?

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 22

PRODUCT-SERVICE SYSTEM

DESCRIPTION / DEFINITION

A product-service system (PSS) consists in selling a product's use as a service rather than as a product.

It is a form of dematerialisation of trade in order to propose a function or a service, often invoiced pro rata of its use, instead of selling a product or an item of equipment.

Product-service systems allow manufacturers to differentiate themselves through an innovative offering, to more quickly impose their innovations and new features, and to move up the value chain by offering more services. In addition, proximity to the customer is strengthened, resulting in greater loyalty, as part of an approach that remains virtuous from an environmental point of view.

Product-service systems can be applied to a wide variety of fields, both in industry and in consumer goods. Manufacturers are therefore concerned both in the definition of their offer (the development of new business models to sell the use and no longer the equipment), and as production centres (seeking solutions from their suppliers to be billed per use and no longer at the machine).

ISSUES (BENEFITS)

In economic terms

- Contracts set up must include incentives so that users have a financial interest in limiting their use and thus ultimately making savings and producing environmental benefits.

In technological terms

- Innovations in performance will also be more liable to be quickly integrated if the overall cost of ownership is reduced for new equipment compared with a previous model that is less efficient.

In terms of business transformation

The benefits for the customer:

- Transfer of Capex expenses to Opex, which limits debt and long-term commitments.
- Consumption adapted to the customers' needs.
- With an obligation to achieve results and not efforts, the manufacturer remains the guarantor of the quality of the offer.
- Better visibility on costs.

In environmental and societal terms

One of the main benefits of the product-service system is that it reduces the environmental footprint of the product: equipment designers will be interested in optimising both the design and maintenance of their equipment to make it last longer and be profitable over a longer period.

FACT SHEET 22

PRODUCT-SERVICE SYSTEM

KEYS TO SUCCESS

In technological and digital terms

The digitisation of economic processes promotes the transformation of business models from possession to use. This represents a real catalyst for product-service systems.

In terms of skills to be mobilised, knowledge and training

- The legal and financial framework must be reviewed to adapt to product-service systems; a reform of rental right may need to be considered. The specific funding method must also be adapted.
- Economic and fiscal measures could be set up to promote the development of product-service systems.

The questions to ask

The elements used to calculate an offer must take into account the following:

- depreciation of the price over a reasonable period;
- user training, user accountability;
- hotline, cost of overhaul, cleaning, before transfer to a new customer.

MATURITY OF THE OFFER

Emerging	Laboratory	**Proven**	**Mature**	Frequent	Pervasive

USEFUL LINKS

Professional organisations
FIM, PROFLUID

Support organisation
http://economiedefonctionnalite.fr/
http://www.club-economie-fonctionnalite.fr/
http://www.inspire-institut.org/category/economie-de-fonctionnalite

FACT SHEET 47

NEW BUSINESS RELATIONS

DESCRIPTION / DEFINITION

In an economic system based primarily on operating margins, companies must constantly renew their offerings and ensure the financing of technological investments, the essential drivers for its sustainability. In order to reconcile the creation of value and preservation of the environment, business models can be re-examined and incorporate concepts such as:

- product-service systems, based on the use of the product rather than on the product itself, in particular by working on the overall cost of the goods used:
  - > working in particular on the transition from the production of a good to the provision of a service (rental-maintenance system, organisation of repair steps, self-service sharing, etc.);
- innovation in business strategy and relationship marketing, focusing on the quality of the relationship with the customer (brand, reputation, community of users):
  - > product-oriented marketing trends with the provision of an additional service to the product (financing, maintenance, end-of-life take-back), use-centric through the sale of the use and not of the product itself (rental, leasing, pooling and sharing) or result-centric *via* the guarantee by the producer that the consumer's needs will be satisfied without taking into account the products.

There are large numbers of examples of channels being reinvented to the detriment of distributors. Logic is at the base of some successful business models. An overall strategic move is emerging in both the B2B and B2C markets. The goal is to preserve a mix between traditional channels and new direct channels. It feeds on a combination of strategic interests and the digital revolution.

These new business models have in common the high speed with which they can be implemented, disintermediation, desectorisation, and a good e-reputation. For disintermediation, the producers or the distributors no longer control the sales channels, which are now digital. From now on, building trust is done on the social networks. Internet users assess the quality of companies and their respect for ethics *via* their exchanges of messages. A good e-reputation is an asset for the company while a smear campaign can be fatal.

There are also new sociological behaviour patterns, in which the satisfaction of use replaces the desire for ownership and in which collaborative modes are developing.

ISSUES (BENEFITS)

In economic terms

- Reinforce the exclusivity of a value proposition:
  - > recognise that powerful and lasting value propositions go beyond the product alone;
  - > integrate vectors related to the brand, usage solutions and the customer experience whose codes are being less and less delegated.

In technological terms

- Control customer knowledge and data:
  - > the new techniques of data analysis are the lever par excellence for direct marketing to act on customer loyalty, customisation, the promotion of new products, facilitating communities, etc.

In terms of business transformation

- Simplify the value chain for simpler and more efficient networks:
  - > reduce the levels of intermediation, through fluid practices and by putting the respective roles of the players in perspective (logistics, negotiation, sales administration, services, final integration functions, etc.).

FACT SHEET 47

NEW BUSINESS RELATIONS

- Seize the opportunity to create new distribution channels to enable visualisation and a more direct relationship between seller and buyer.

In environmental and societal terms

Any company project that aims to change its business model towards a product-service system or an innovative business strategy will have to be efficient from an economic point of view and beneficial from an environmental point of view (no rebound effect or pollution transfer).

- Act on the complete life cycle:
  - > the Internet of Things is shaking up the management of product life cycles. The sale of a use will increasingly involve remote control, remote maintenance, recycling management, etc.;
  - > the rationale of winning manufacturers will increasingly be based on the direct control of an ecosystem without any need for intermediation.

KEYS TO SUCCESS

In technological and digital terms

- Invest heavily in data:
  - > manufacturers and distributors are sprinting to control data. By controlling the sale transaction and the payment transactions with end customers, distributors still have a key position with which to analyse and create value with data.

In terms of skills to be mobilised, knowledge and training

The process also requires re-examining the different activities and skills of the company. The greater the change in the company's offer is in favour of the environment, the greater the need for change support.

The questions to ask

- Re-examine your value propositions in order to develop and clarify them.
- Move up the value chain towards design and supply control:
  - > ensure the shortest possible coordination between the design of the offer and its marketing.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET 61

WASTE RECOVERY

DESCRIPTION / DEFINITION

The recovery of waste consists in reusing waste (organic or material) for energy recovery (exploitation of the deposit of energy contained by the waste *via* the production of electricity, heat or steam) or material recovery (use of all or part of the waste to replace an item or a material). Energy or material recovery can be carried out during production, in the operational phase or at the end of a product's service life. The French Agency for Environment and Energy Management (ADEME) defines it as follows: " *the reuse, recycling or any other action to obtain, from waste, reusable materials or energy* " (Law of 13 July 1992). Energy or material recovery is driven by a number of factors, including:

- rising environmental concerns;
- the increase in price and the scarcity of virgin raw materials;
- the greater price volatility of secondary/virgin raw materials.

Against this background, a proliferation of incentive and regulatory tools can be seen emerging that structure the collection and sorting of waste (recycling rate, standards, streams, extended producer responsibility). It is also worth noting the significant weight worldwide of major French groups involved in the collection and treatment of waste.

Finally, industrial and regional ecological policies constitute important levers for competitiveness and re-industrialisation.

ISSUES (BENEFITS)

In economic terms

- Recovery of increasingly scarce resources (the El Dorado of urban mines).

In technological terms

- Tele-operated sorting allows operators to no longer manually handle waste, but point on a touch screen to the items to extract from the sorting chain.

In terms of business transformation

- The treatment of waste directly on-site enables a reduction in transport costs.

In environmental and societal terms

- Reduction of the environmental impact of waste.
- Transition from the status of waste to status as a secondary raw material.

KEYS TO SUCCESS

At the technological level

- Experiment with new recycling and recovery processes.
- Develop new sorting techniques (by shape, colour or material), potentially based on machine learning.
- Develop sensors dedicated to intelligent waste management (ultrasonic sensors to indicate the filling rate of a container, for example).
- Extend selective collection to flexible plastics (2022).
- Develop further the techniques for recycling composites.

FACT SHEET 61

WASTE RECOVERY

In digital terms

- Develop software platforms dedicated to waste management such as Enevo, Compology or BigBelly.

In terms of skills to be mobilised, knowledge and training

- Develop still-little-developed energy and material recovery sectors, especially strategic metals, plastic materials, end-of-life vehicles (ELV), etc.
- Develop deconstruction and/or transport means recovery sectors: trains (Culoz, Chalindrey, Le Mans, etc.), aircraft (Tarbes and Châteauroux), heavy civil and military vehicles (Roanne, etc.), ships (Bassens-Gironde), pleasure craft (APV project), etc.
- Innovate in the organisation of stakeholders.
- Build on the experience of industrial and territorial ecology (EIT) such as the Acteis project in the region around Dunkirk, which aims to support companies in the implementation of industrial ecology synergies (reuse of energy & materials, pooling of waste management).
- Develop the French sector for the recovery of strategic metals and associated technologies: *fuming* (solid and liquid phase), supercritical oxidation and the use of ionic liquids in particular.
- Support the energy recovery sector in the agricultural sector (anaerobic digestion, the Emaa plan).
- Go beyond the circular economy towards industrial ecology.
- Take into account recycling right from the design phase of a product, so that the reuse of the material is considerably simplified and its quality improved.
- Look for export opportunities.

The questions to ask

- What is the influence of the replacement of conventional materials by other more complex materials (multilayer plastics for example) on the recycling of products?
- What are the separation and treatment solutions for the new waste stocks?
- How can we avoid downcycling, i.e. the loss of the intrinsic value of a material through a cycle no longer allowing the production of the same type of product?
- How can we monetise the environmental benefits of recycling?
- How can we harmonise the principle of extended producer responsibility to all recycling streams?

▸ MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

FACT SHEET X01

MONITORING, FORESIGHT AND ECONOMIC INTELLIGENCE

DESCRIPTION / DEFINITION

With globalisation and the advent of digital technology, information control is imperative. The globalisation of the economy justifies constant information monitoring on an international scale in order to maintain the competitive advantages of industrial companies. More and more data are available, on increasingly diverse formats, and the technologies associated with information collection and exploitation are also changing dramatically. Transforming this information into a strategic advantage, using intelligence techniques as well as economic protection systems and lobbying, is now essential.

Business intelligence consists in collecting technological and strategic information to anticipate changes and innovations. It can affect many areas and a company must correctly define the scope of research (commercial, competitive, environmental, financial, legal, marketing, media, political, regulatory, sectoral, societal, strategic, technological, etc.).

Foresight is an approach that involves studying technical, scientific, economic or societal factors in order to predict situations that may arise from their combined influences. The result is scenarios of possible medium-term developments.

Economic intelligence consists in collecting the information needed to understand the interrelations of the ecosystem and to analyse them, in order to anticipate the action to be taken and thus benefit from a competitive advantage, if possible strategic. Economic intelligence can be defined as the set of coordinated actions of research, processing and dissemination, with a view to the exploitation of information useful to economic stakeholders. Intelligence is the tool for forward planning. These various operations are carried out legally with all the guarantees to protect the company's assets, in optimal conditions of lead time and cost.

Useful information is that needed by the different decision-making levels in a company or local authority, to develop and consistently implement the strategy and tactics necessary to achieve the objectives set by the company, the goal being to improve its position in its competitive environment. These operations within a company are organised around an uninterrupted cycle, generating a shared vision of the company's objectives.

ISSUES (BENEFITS)

In economic terms

- Strategic intelligence can be used to innovate, anticipate and limit risks (impact of a regulation, detection of counterfeit goods, and so on).
- The sharing of information and knowledge within a company allows employees to be more efficient in their daily work, and helps unite employees around collective projects.
- Monitoring saves time by using what already exists.

In technological terms

- Monitoring, foresight and economic intelligence are designed to help guide a company's development and technological innovation strategy, based on the weak and strong signals from the market and the economic environment of the company's business.

FACT SHEET X01

MONITORING, FORESIGHT AND ECONOMIC INTELLIGENCE

In terms of business transformation

- Any organisational change must be made by anticipating market and technological developments, hence the importance of economic intelligence. It is essential that every employee of a company be allowed to benefit from monitoring tools and operations in line with their professional objectives, in order to give them a strategic vision in the medium-long term.
- Similarly, it is essential to be able to push information outward in order to influence the economic environment of a company.

► KEYS TO SUCCESS

At the technological level

- Reflect on the monitoring methodology before focusing on the use of tools.
- Set aside time to analyse and summarise information.
- In the medium term, implement a big data approach to process structured and even unstructured data, and the use of semantic methods for information searching.

In digital terms

- Utilise the information existing inside companies.
  - > *Knowledge management* is also part of one of the activities of economic intelligence and can be used to optimise interactions between stakeholders, so that not only is information properly disseminated, but the exchange of information is also optimised.
- Promote the efficient use of digital tools and the Internet to extract all the added value without loss of productivity for employees.
  - > Manage the multiplicity of available sources of information.
  - > Use social networks and feed aggregators to optimise information retrieval channels.

In terms of skills to be mobilised, knowledge and training

- Economic intelligence is a general-purpose skill that needs to be instilled among every company employee across the board. First and foremost, it requires setting up shared methodologies and tools.
- Each stage of the monitoring cycle requires specific skills: Internet searching, document analysis, visits to trade fairs, and so on.

The questions to ask

- The security of information systems and the data they process is a major challenge for businesses. What technical steps must be taken to protect a company's strategic assets while at the same time complying with the law? How should companies prepare for the entry into force of the General Data Protection Regulation (GDPR) in May 2018?
- Digital technology multiplies the power of corporate means of influence by enabling a direct relation with public opinion which bypasses the traditional relays (politicians, the media, etc.). What are the influence mechanisms? How can companies prepare and use them to their advantage? How should companies organise the response in case of attack?
- There is more and more information; how can companies deal with information overload?

► MATURITY OF THE OFFER

Emerging	Laboratory	Proven	**Mature**	Frequent	Pervasive

FACT SHEET X02

MARKETING AND STRATEGIC BREAKTHROUGHS

DESCRIPTION / DEFINITION

To differentiate themselves on their markets, companies must be innovative. The main idea is to surpass their competitors by offering a product or service perceived as unique by potential customers. As the digital transformation gains ground everywhere, marketing, which was already affected, will be even more so:

- whether in the quantity of data, their quality and their processing in real time and in their visualisation to extract the material facts;
- this means marketers will have to identify their data (internal and external) better, make them communicate with each other to make them more meaningful, in a customer-centric context, so that they can extract the needs inherent to each customer. It also involves equating the right KPIs to make sure that marketing operations are in line with the company's defined objectives.

Communication requires more and more interactivity, but without expanding the teams. In order to provide a quality of service and response to the various persons concerned (or connected objects), the marketing department will use technological means to support it. These may include artificial intelligence, chatbots, or simply feelings analysis to anticipate the requests of the persons concerned (but the list is long).

From a customer relationship perspective, artificial intelligence will inevitably feed the hyper-customisation of the customer experience through the use of objects that will extend the utility of a product-service. *Machine learning* will therefore become a key lever for conversation and dialogue between brands & consumers. It will input tools such as chatbots and interactions on the fly.

New communication formats are also appearing with social networks and instant formats. The public prefer short, simple but original formats that highlight the user. The spotlight is no longer on a product or a solution: the user and the use are central to the message, the ideal situation of course being when customers generates the content themselves. And since there may be several uses for a product, each type of customer will require specific content, the famous storytelling. As a result, marketing investment will invariably grow to design content that is innovative, relevant and differentiating.

In this respect, *real-time marketing* (RTM) relies on the detection of engaging signals to associate them with a profile and then use them in a more personal form of communication. But there can be no RTM without available data. Open data offers the richness needed to achieve this goal of individualisation of communication, and incites all of the stakeholders in communication to reinterpret traditional relational marketing.

As a result, marketers are starting to undergo a profound change in mindset to move from static, volumetric possession of data to dynamic, cross-use of it. Access to data more than their ownership will be an essential lever in the relational strategies of companies.

ISSUES (BENEFITS)

In economic terms

- Stay in step with the latest marketing and strategic trends, in connection with technological convergence that is having an ever-increasing impact.
- Benefit from growth drivers by adopting new vectors of communication to address different audiences.
- Ensure the sustainability of the company through a renewal of its marketing / strategy methods and processes to reach a dynamic, changing market target.

FACT SHEET X02

MARKETING AND STRATEGIC BREAKTHROUGHS

In technological terms

- *Deep tech* (artificial intelligence, robotics, Internet of Things) represents innovation and growth drivers for a post-uberisation era, with solutions that really aim to change the world and our modes of production, not just business models.
  - > Analyse the customer engagement before, during and after a purchase, almost in real time, or even anticipate their needs.
    - Sensors and IoT also have an important place in this system of data creation and analysis, by following consumer pathways for example.
  - > Significant impact of virtual reality technologies on the identity and marketing of many companies in many industries.

In terms of business transformation

Emerging marketing and strategic breakthroughs will strongly influence a company's ability to adapt and evolve. The adoption of these new technological practices represents a real sustainability issue for a business and strongly influences its ability to seize the opportunities associated with the current transition period, at the crossroads of technological convergence and large-scale environmental and societal challenges.

► KEYS TO SUCCESS

In technological and digital terms

- Broad appropriation of emerging technological concepts in order to disseminate a cross-cutting technological culture that is able to reposition the customer's need as a central element of the company's development strategy.
- A successful digital transition to foster the establishment of numerous synergies between departments and between different employees, to serve the strategy's objectives in terms of change.

In terms of skills to be mobilised, knowledge and training

- A wide range of skills to fully understand the potential of deep tech, especially for marketers (continuing vocational training in digital technology).
- A vision of the changes in current needs and anticipation of the behaviour patterns of future generations in order to adapt current strategy to emerging needs.

The questions to ask

- What type of customer focus for my company? Which targets? (end customers, distributors, integrators, etc.)?
- Foresight in terms of the changes in the typical customer and their needs.
- Objective analysis of the target customer access channels and identification of new marketing and strategic opportunities.

► MATURITY OF THE OFFER

Emerging	Laboratory	Proven	**Mature**	Frequent	Pervasive

FACT SHEET X04

INTERNATIONALISATION AND EXPORT

DESCRIPTION / DEFINITION

Exporting should not be seen just as a search for outlets, but as a true aim of the company to become international. All employees must feel they are involved. It is a global initiative. Exporting must be integrated into the company's strategy. Successful exporting is often the result of a mix of well-structured international strategy, seized opportunities and daring.

On paper, many countries seem attractive but their accessibility can be problematic. The average time to have sustainable business with regular flows is two years. You have to take the time to build personal relationships with local partners. Surrounding yourself well, prioritising your target markets, and sequencing your approach to international development are all key factors for the success of an export project.
You need to understand the development, the cultural and business characteristics, the distribution network, the regulations in force, etc., and to constantly update your various business plans depending on opportunities to be seized, market changes, and the speed of change.

There are different ways to enter a foreign market, and choosing them is decisive for the chances of success of an international project. In some cases, it may be wise to work with a French business partner (agent, trading company, large company, peer exporter); in others, it is cooperation with a local agent or distributor that will be the right solution.

ISSUES (BENEFITS)

In economic terms

Exporting firms are distinguished by higher productivity, staffing, wages and profitability. These companies generally already have an investment and hiring dynamic before exporting, which is thus the crowning step to a successful development strategy.

The choice of internationalisation is fundamental for several reasons:

- because it gives extended visibility to a brand or product, visibility that will have a positive impact on customers and financiers;
- internationalisation also allows SMEs and MSBs to gain new markets, sources of growth drivers and new customers and therefore, *ultimately*, better profitability, which reduces fixed costs;
- finally, internationalisation allows growing companies to face new competition, which makes them accelerate their innovation processes even more.

In methodological terms

The company director must be clear about the strategy.

- Is the purpose to expand the company's market, develop the customer offer, access a technology? Whatever the expected added value, the objectives must be formalised, approved by corporate governance and discussed with management.
- The company director must then define the development zones and target markets. The business model must have meaning in terms of product, customers and suppliers.
- Finally, the company director must launch a preparatory study. This step is sometimes long and laborious, but necessary to gain control of the target market, and it represents a real time saver during the product launch.

FACT SHEET X04

INTERNATIONALISATION AND EXPORT

Under these conditions a company can specify the degree to which its offer or product corresponds to the market and the positioning of its competitors. The company will also be able to identify the logistical and technological constraints and opportunities involved, as well as the various export subsidies available. Finally, the company can build a business plan specific to each market and define an appropriate marketing and communication plan.
These steps are the logical follow-up to the thinking that helps structure the internationalisation process and determine the best way to make the move: export, support from a local distributor, or setting up locally *via* a franchise, a subsidiary or the acquisition of a local structure.

In terms of business transformation

Internationalisation, whether exporting or not, must be integrated into the overall strategy of the company and be an element of its performance. More than the purely commercial issue, the technological issues (being part of the dynamics of the global industrial system thanks to the mastery of technologies) and the organisational issues (changing the organisation of a business to adapt to the global environment) are essential.

KEYS TO SUCCESS

At the methodological level

- Map potential markets and considering them on the basis of several criteria: entry tariff barriers, geographical proximity, competitive environment, standards and regulations, etc.
- Pay attention to *place to market* as there can be a time to market.
- Test the product or service with a panel of consumers or country experts.
- List all the expenses necessary to approach, then enter the target market: participation in trade fairs, adaptation of the offer, translation of your website, recruitment of partners or employees, legal fees, etc.
- Train the entire company: from design & engineering to the production and support departments.

MATURITY OF THE OFFER

Emerging	Laboratory	Proven	Mature	Frequent	Pervasive

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