INDUSTRY 4.0 SKILL SETS FOR AEROSPACE

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EXECUTIVE SUMMARY

- A new revolution is underway. It is supported by equipment connectivity, technology and data. It will have an impact on each and every company department.
- Lack of resources and lower production costs are prompting companies to automate their processes to meet customer demands.
- This transformation is resulting in productivity gains ranging from 40% to 60%.
- A 4.0 factory has in place an information system that allows users or installers of a piece of equipment to measure their performance and that of their machine, or work cell, in real time.
- Data enables 4.0 workers to make a greater contribution to process optimization.
- In a 4.0 factory, the equipment is more specialized than the worker.
- The corporate culture needs to move from hierarchical to empowering and towards a culture of learning.
- In a 4.0 factory, professional disciplines cooperate; they do not protect their know-how but share it to facilitate decision-making.
- Analysts and computer programmers are getting more involved in production. The latter are looking at the operation of machinery, equipment and industrial processes.
- The leader must become a “digital leader,” i.e. a person capable of anticipating digital changes.
- The difficulty of integrating systems with those already in place slows the process of industrialization 4.0.
- An SME that has not planned to reinvest capital in equipment automation and connection will have a hard time making the shift.
- It becomes imperative to document this transformation to preserve the company’s knowledge.
- The human aspect is undoubtedly the greatest challenge of this transformation.
- Workers in all trades, including entrepreneurs, need to develop broader relational and technical skills to participate in the development of the entire company.
- Essential skills in the digital age: technology and the digital world (prerequisites); relational and organizational; mathematics and programming; leveraging of data; integration and automation; process optimization; and 4.0 business management and co-opetition.
- The availability and costs of technology are making this transformation possible. This change will be rapid and disruptive. New competition rules are emerging.
- Industrial ecosystems and platforms are the next pathways for growth in manufacturing firms. At the very least, they will facilitate business synergies and inter-company co-opetition.
- In the digital age, it is common to see academic research projects being conducted on business problems and issues.
- Research and support for digital development needs to be stepped up to help the manufacturing industry remain competitive and develop industrial synergies.

PROJECT OBJECTIVES

The overall objective of the project is to create a “Industry 4.0 Skill Sets for Aerospace” to equip educational institutions (professional, technical and academic) to modify and adapt their training programs for future company needs. This project, supported by the Conseil emploi métropole (CEM), also aims to assist companies that will be taking the 4.0 shift in the coming years. This project, therefore, intends to promote a better alignment between training and jobs in aerospace.

This project is a follow-up to one of the recommendations of the White Paper “Propelling the Talents of Aerospace Towards Industry 4.0” from the 2016 Aero Talents SME Forum, published in September 2016:

> *Develop a “4.0 Skills Guide” through concerted and continuous consultation with aerospace companies, with the participation of educational institutions of all levels, research centres as well as the aerospace cluster and its partners. This initiative will allow for an analysis of current and future critical skills, and to adapt high school, college and university programs to company needs.*

The Industry 4.0 Skill Sets for Aerospace aims to:

1. Raise awareness about the changing skills required by the aerospace industry workforce to tackle the new industrial revolution.

2. Define the existing jobs that will be affected by this industrial revolution and compare current tasks and skills with those that will be required for a transition to 4.0. The list of new skills will have an impact on the following training:

    a. Vocational training

    b. College training

    c. University education

    d. Ongoing company training of current employees

Note to the Reader

Discerning readers will use the various elements presented in this guide to assess their own situation. We hope that this guide will enable readers to appreciate the strategic importance of the industrial transformation now underway. We invite them to take a futuristic view of the evolution of their company or services. In addition, we believe that Industrialization 4.0 is in its infancy. New business models still have to be developed. However, for us, one thing is clear: today’s companies that have made the 4.0 shift will be tomorrow’s industry leaders.

METHODOLOGY

To carry out this project, we met 35 people in 13 companies and 2 consultants specialized in digital transformation. The people consulted had to be involved in the 4.0 shift. We met with executives, engineers, project managers, technicians, professionals as well as training consultants and human resources personnel. They were asked to talk about the transformations and the changes they have experienced or are preparing to experience. A comprehensive literature search was also conducted to prepare an interview guide.

CONTEXT

In 2016, the aerospace industry in Québec generated sales of $14.4 billion and employed approximately 40,000 people. Québec's aerospace workforce is the sixth biggest in the world[1]. The industry is composed of numerous OEMs, world-class equipment manufacturers and nearly 200 SMEs, making it one of the most dynamic in the world. In Québec, in 2017, it was still possible to build an entire airplane within a radius of 100 km. However, the industry is changing. The economic recovery has been slow in coming. The supply chain is consolidating. Production continues to relocate to the South and Asia. Contracts at fair value are scarce. Gross profit margins are declining. The production of parts is becoming a commodity. And machining or assembly centres are specializing. Small players are therefore under great pressure to adapt.

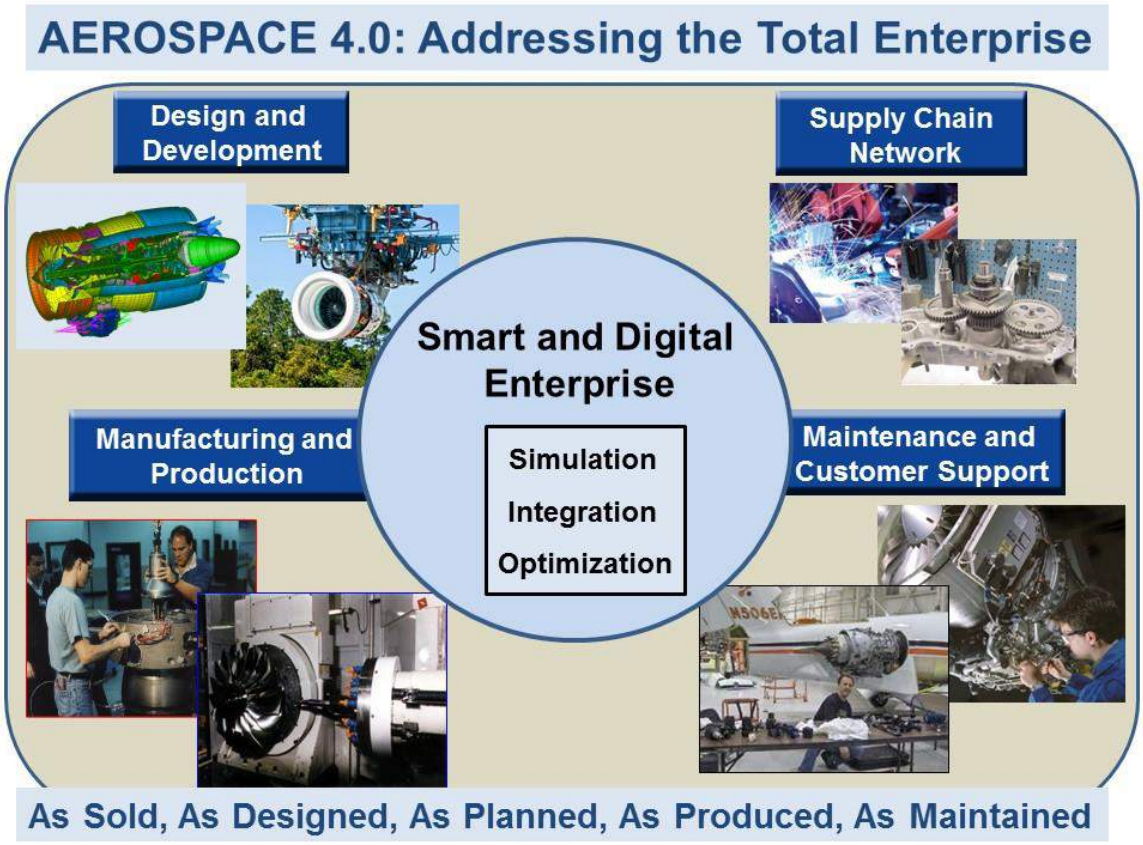
A Revolution Is Underway

The industrial world is in full revolution. The business environment is volatile and uncertain. The pillars that made possible the success of the manufacturing mode of production are crumbling. We are transitioning to a new way of looking at industrial production. Aerospace is no exception. The adoption of new innovations is accelerating. All players in the aerospace cluster need to reconsider the nature of their role, their ways of thinking, and how they deliver their products or services.

Industrialization 4.0 is well integrated into the business concerns of innovative aerospace companies. Guided mainly by large companies and a few small companies, this new way of doing business will impact the entire supply chain.

[1] Ministère de l'Économie, de la Science et de l'Innovation, 2017.

Figure 1: Industry 4.0 and its Impact on the Entire Company



Source: Aerospace 4.0, Hany Moustapha, Professor and Director, AÉROÉTS, École de technologie supérieure, Senior Research Fellow, P&WC, 2016.

The Industry Is Becoming Connected

The world is becoming increasingly connected. We are experiencing this connection daily through many social platforms. In 2017, *there were about 6.6 billion devices that communicated with each other. This number is expected to increase to 20 billion by 2020*[2]. *This connectivity of data and devices is a decisive factor in Industry 4.0*[3]. In fact, real-time data makes it possible, among other things, to anticipate and quickly predict changes, and better manage the risks associated with the business. They become a corporate asset that creates value for the organization. With data, manufacturing and assembly become more intelligent.

The company of tomorrow will have to respond quickly to a demand for customized industrial products, and thus produce small, even individualized batches. This implies a very high degree of flexibility and a high modularity of industrial equipment. This complexity requires developing a new way of managing the business, organizing operations and, by the same token, acquiring new knowledge.

[2] http://www.gartner.com/newsroom/id/3165317,accessed January 15, 2017.
[3] Feuille de route de l'Industrie 4.0, Gouvernement du Québec, MESI, 2016.

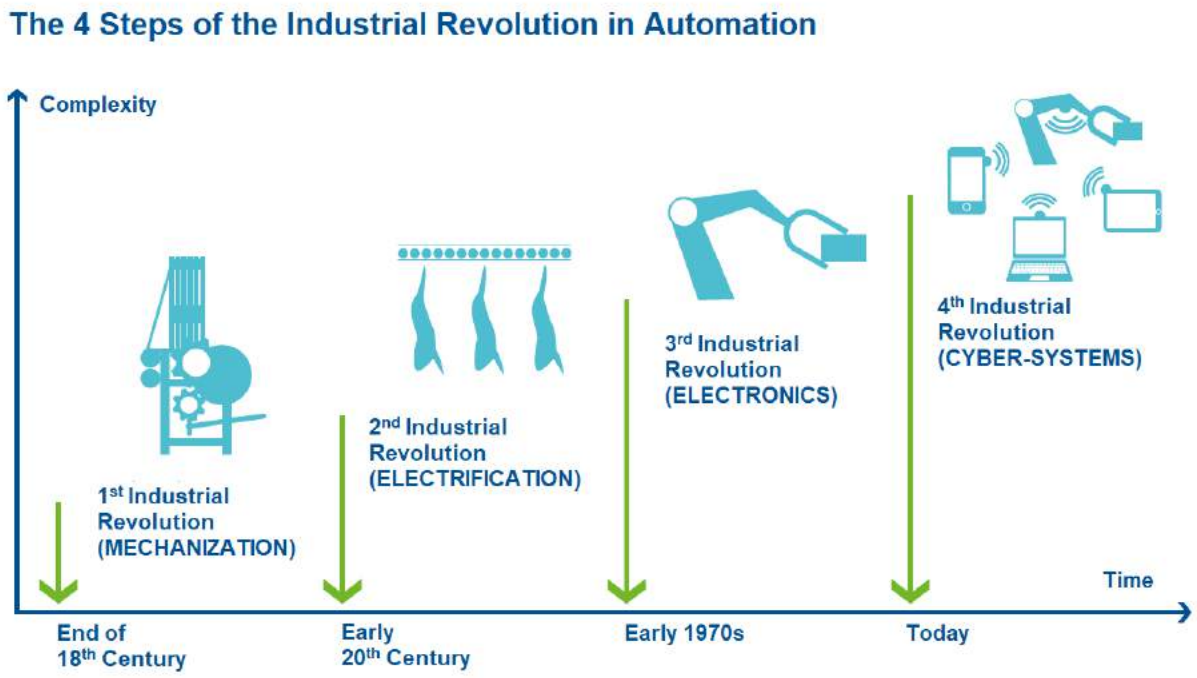
The Arrival of New Business Models

It is through learning new processes of interconnected and collaborative design and manufacturing that this shift can be undertaken[4]. Relational competitiveness is also at the heart of Industry 4.0. The human is the central player in ensuring the success of this transition. As we can see in Germany, this shift involves new modes of interaction between economic actors, their customers and training institutions, both inside and outside the value chain. This ability to experiment together does not only involve technology. It also requires the definition of new and better integrated business models and ecosystems linked, inter alia, with emerging industrial service platforms. *A change in which versatility and cross-cutting knowledge between companies from different sectors and disciplines are becoming a central issue for the players of this digital revolution*[5].

The Digitization of Companies

There is still confusion about what 4.0 industrialization is all about. Indeed, many talk about automation and robotization when it comes to the digitization of companies. Robotization of the manufacturing sector has existed since the 1970s. It has been fostered by a boom in electronics and the accessibility of computers. This phase is called industrialization 3.0. A company can therefore use robots and not be 4.0. Figure 2 shows the different phases of industrialization.

Figure 2: The 4 Steps of the Industrial Revolution in Automation

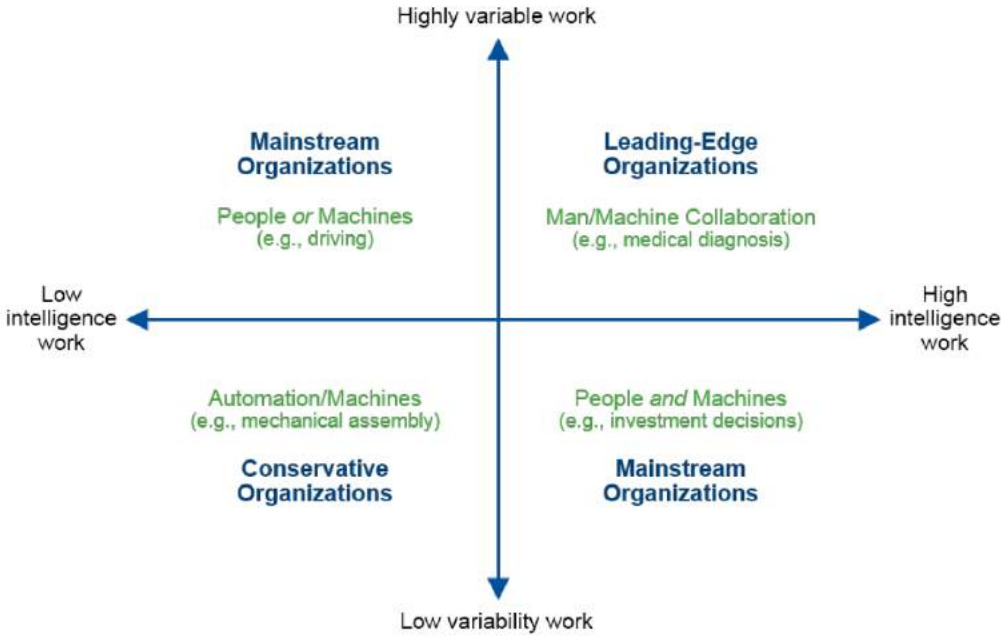


Source: Guide pratique de l'usine du futur, Enjeux et panorama de solutions, Usine du futur, FIM, AIF, 2015.

[4] Industrie 4.0 : Comment caractériser cette quatrième révolution industrielle et ses enjeux? KOHLER Consulting & Coaching, Dorothée KOHLER et Jean-Daniel WEISZ, 2016.
[5] Idem.

The aerospace manufacturing sector, due to the small size of most of its companies and the nature of its products, is still behind in terms of automation and robotics. Indeed, as shown in Figure 3, the degree of automation of a company depends on the complexity of the product to be manufactured. The complexity of the information and the needs determine the degree of intelligence of the equipment and, by the same token, the possibility of automating.

Figure 3: Automation Constraints



Source: *Beyond Automation: Digitalization Changes Business Process Design and Execution*, Gartner, Janvier 2017.

Undertaking this transition requires a good understanding of the current and future needs of the business environment. A management team needs to assess the changes that will have an impact on the company's competitiveness. The most advanced started the shift more than 5 years ago. They did not decide to invest in 4.0 on a whim. These companies broke through the technological barrier because their vision and industrial maturity made it possible to envision this transition, no matter the size of their company. This revolution is not just for big players.

MOTIVATIONS BEHIND THE SHIFT

All manufacturing industries are affected by the scarcity of labour. Aerospace is particularly affected by this situation. Several positions available on the market are not being filled. This lack of resources is forcing companies to automate their processes to meet customer demand. Globally, low-cost machining centres are putting downward pressure on prices. Thus, to stay competitive, win bids and sign long-term agreements, companies need to increase their productivity and demonstrate their ability to better manage risk. This shift to 4.0 is also a way to maintain jobs. Indeed, companies that are more advanced in the transformation have maintained jobs and created new ones. They have added new skills and developed the full potential of their existing workforce in the use of technologies associated with production.

Productivity Gains

It should be noted that the companies that have made the shift have experienced very positive business impacts. They tell us that it is becoming easier to engage in long-term contracts that favour both parties because they can better predict productivity improvements. Current improvements are in the range of 40% to 60%. We are seeing gains in reducing maintenance times, lowering health and safety costs, and accelerating product development.

A REVOLUTION: A NEW WORK ENVIRONMENT

In this section, we invite the reader to place themselves in the future and become a visionary. To facilitate understanding of this revolution, we present a model based on observations and discussions with companies that today have real 4.0 factories. It may be that the workplace we are going to present does not correspond to your current reality. This is a paradigm shift. We ask you to use your ability for anticipation.

Each of the players in the industrial cluster will need to build on their respective strengths to counter current threats and turn them into opportunities. We are aware that there will be some cohabitation between the modes of production. Considerable development work will need to be done in most settings to switch from collecting data manually, on paper, to an automated online data collection method in real-time. For some companies it will be a long transition and, for others, it will mark the end.

Accessibility of Information in Real Time

A 4.0 factory has set up an information system that allows users or installers of a piece of equipment to measure their own performance and that of the machine or work cell, in real time. The connectivity of systems, machines, employees and products gives them access to this information. They are in continuous communication with the production processes (design, manufacturing, logistics and maintenance) as well as the manufactured products.

Data Analysis

Machines and tools, incorporating intelligent components and subsystems, bring together production equipment that can integrate information and use it to meet a specific function. Analytics and data modeling provide information to the user about variations in processes. It can make decisions based on the interpretation and analysis of this information.

Leveraging Intellectual Capacities

The data allows 4.0 workers to make a greater contribution to process optimization. Whether an engineer or an operator, they have to present solutions to automate certain tasks related to their field of expertise. The technology developed allows them to increase their production capacity. They can manipulate several pieces of equipment without necessarily increasing their physical effort. Their intellectual capabilities are the most important.

Human-Machine Collaboration

Collaborative internal equipment and networks are helping workers to act faster and easier. For example, the virtual tools to which they have access allows an engineer to speed up the design time, facilitate learning and reduce the risk of errors or variations. Algorithms and programming are part of the daily lives of 4.0 factory workers. They can relegate routine activities to robots, equipment or the system. In a 4.0 factory, the equipment is more specialized than the worker.

An Empowering Learning Culture

The factory 4.0 quality management system is built around process dynamics and the development of worker accountability. Autonomy and ease of decision-making are only exercised within the framework of clear rules, with management processes focused on the added value of engineers, technicians and operators. This revolution, therefore, comes with the need to review the traditional decision-making structure. *The corporate culture must shift from hierarchical to empowering and strive towards a learning culture*[6]. Collaboration is at the heart of product and process innovation. These are social networks adapted to technical issues, enabling the sharing of information, the management and prioritization of ideas, the management of technical problems, project and program management, the management of product portfolios, etc.

Internal Entrepreneur

These collaborative tools make it possible to deploy the "augmented man," i.e., a man equipped through these interfaces with all the information he needs: plans, ranges, instructions, technical data, training, history, etc. The result is that this augmented man is empowered and becomes a true internal entrepreneur[7].

Multidisciplinary Cooperation

Digital engineering facilitates the modeling and simulation of processes or products. These tools make it possible to develop the processes, and to optimize them in the virtual world, at a very low cost once the initial digitization investment has been made. This involves the implementation of a large number of simulations carried out iteratively, involving all the disciplines involved. In factory 4.0, the professional disciplines cooperate. The professionals do not protect their know-how, they share it to facilitate decision-making. Workers at this factory are expected to develop general skills to ensure their versatility and employability.

The Arrival of Computer Professions

Graduates of vocational and technical schools are becoming important players in design. For their part, engineers are becoming coaches to develop the technical players around them. The compartmentalization of disciplines has no place in factory 4.0. The operator and technician play a bigger role in the product life cycle. They are privileged informants thanks to their position on the front line of production. Analysts and computer programmers are also becoming involved in production. The latter are focusing on the operation of machinery, equipment and industrial processes.

[6] Feuille de route de l'Industrie 4.0, Gouvernement du Québec, MESI, 2016.
[7] Guide pratique de l'usine du futur, Enjeux et panorama de solutions, Usine du futur, FIM, AIF, 2015.

THE CHALLENGES AND ISSUES RELATED TO THE 4.0 SHIFT

Digital Vision and Maturity

The transformation of a company does not happen without some disruption. A starting point is to establish a common language or rationale for making this change. The ability to assess a company's digital maturity is an essential skill. Everything starts from the management team's governance and vision. The challenge is to get all the internal players to understand what the company's 4.0 shift is all about. We need to create a sense of urgency. A leader who has no interest in technology will not be able to play a direct role in the success of this transition.

Digital Leadership

It will also be more difficult for the company to achieve change if the internal culture promotes the hierarchy of roles rather than the sharing of information, innovation and transparency. We must not forget that the desire to learn continuously, relational skills and the ability to adapt are the success drivers for Industry 4.0 players. The leader must therefore become a "digital leader," i.e., a person capable of anticipating digital developments. This leader will have to accept not having all the answers. Knowledge and the tracking of trends will come from everywhere: from his/her teams, but also other departments of the company, the Internet, the competition, etc. *It is necessary to define a digital governance that will encompass the policies, structures, roles, rules, processes and standards necessary for the application of the "digital workplace" in an optimal and sustainable way*[8].

Compatibility of Equipment

The difficulty of integrating existing systems contributes to slowing the process of industrialization 4.0. Many pieces of equipment have informational protocols that are not compatible with the computer ecosystem. The presence of multiple information management subsystems, such as VBA databases, results in additional transformation costs and system connection challenges. This is commonly known as "Shadow IT." This name is frequently used to designate information and communication systems developed and installed within organizations without the approval of the Information Systems Department. Thus, the definition of a technological architecture and a clear governance in terms of the use of the various systems and subsystems becomes imperative to the success of the project.

Harmonization of Business Processes

The difficulty of automating business processes is a challenge of industrialization 4.0. Automation of these processes is the mechanism by which the data, information and processes associated with the company are managed and transferred in technological ways. The acceleration of real-time information and the prominence of data resulting from the connection of the various systems are prompting this automation. It becomes a prerequisite for industrialization 4.0. Harmonizing business processes with the company's IT ecosystem requires specific systems integration skills – and a lot of time and money.

[8] How Mature Is Your Digital Workplace?, Digital Workplace Group, 2016.

Capital Investments

It should be noted that some companies have fallen far behind in their industrial processes. This delay is due, in part, to the nature of the products offered and the expectations of customers. Several SMEs in the aerospace industry have fewer than 4 customers. They are highly dependent on them. It is difficult to carry out a major transformation while continuing to deliver with the quality and time required. Capital investment could be too risky. This capital is often frozen in the liabilities of the company. The SME that has not planned reinvestment of capital in the automation and connection of equipment will have difficulty making the shift.

Automating and Digitizing the Company

Moreover, funding institutions are not always prepared for this transformation of the manufacturing environment. Despite the subsidies offered, financial institutions remain hesitant to invest in digital transformation. Indeed, for many companies this transformation requires investing in both the automation of production and the digitization of the workplace. Before experiencing growth, companies making the shift will experience a decline in financial performance and ratios, which does not please traditional lenders. Digital leadership, therefore, needs to also be developed within the financial community.

Loss of Existing Skills

When a company initiates the automation of work methods, it asks its operators to analyze their tasks to eliminate manual interventions. We have observed that existing trades skills can be lost in this transformation. The expertise of a professional or a senior technician facilitates the automation and configuration of tasks associated with production. This phase of designing the new production model provokes discussions, problem-solving processes, trials and errors. It becomes imperative to document this transformation to preserve the knowledge of the company. Learning management systems need to be developed at the same time as the transformation. We noted that many companies are developing an internal learning network commonly called a “corporate wiki”. This platform may include specific videos, a technical chat system, frequently asked questions, troubleshooting procedures, etc.

Skills Development

The human aspect is, without a doubt, the biggest challenge of this transformation. The costs of developing the workforce are significant. This development must be done at all hierarchical levels. There are no miracle solutions. The quality of the investment in employees will guarantee the success of such a project. According to the participants interviewed, floor workers are not reluctant to change, especially when the nature of the project and business issues are well presented to them. The change management strategy and the skills development plans, therefore, need to be carefully prepared to ensure the success of this transformation.

PRESERVING EXISTING SKILLS

A digital transformation cannot be achieved without maintaining existing industry-specific skills. Companies that are advanced in the process have employees who are trained and specialized on their team. They are simply fewer of them. They become the subject matter experts (SME)[9]. These are people who have the most thorough knowledge or skill. Workers in all professions, including entrepreneurs, need to develop broader relational and technical skills to participate in the development of the company as a whole. Thus, new skills are added to existing skills, which we will explain later. Figure 4 presents the skills to be preserved during the digital transformation. This Figure is taken from the report produced in 2014 on the inventory of critical skills in aerospace. They are placed in order of priority from 1 to 6 (1 being the most critical) for each of the positions.

Figure 4: Critical Skills in Aerospace

	Machinist	Assembler	Technician	Methods Agent	Scientific Personnel	Supervisor
1	Perform the reading and interpretation of measurements	Assemble a subassembly	Interpret aeronautical-related technical drawings	Interpret plans, drawings and assembly and installation drawings	Ability to design solutions as needed and taking into account constraints	Understand the role as a supervisor of a work team
2	Machine simple parts through manual or automatic programming	Apply work procedures	Produce and modify programs for numerically controlled machines	Contribute to the optimization of the manufacturing process	Respect deadlines	Manage performance indicators and performance problems (difficult conversations, mobilization, discipline monitoring and clarification of expectations)
3	Versatility: ability and interest to work on multiple machines	Install sealants and glue-bond aircraft structural parts	Ensure conformance of dimensional and geometrical characteristics of aircraft components	Develop and modify workbooks	Knowledge and use of methodological approaches specific to aerospace engineering	Organize and manage the production of goods and services
4	Ability and interest in continuous learning	Versatility: ability and interest to work on multiple tasks	Exploit the possibilities of machining, forming and assembly processes	Extract and modify the information of 3D models for the production of assembly manuals for aircraft structures	Ability to communicate complex engineering concepts effectively, including understanding, presenting, reading and writing in an effective way reports and design documentation	Work methodically
5	Interpret complex drawings related to machining on numerically controlled machine tools	Perform mechanical assembly work	Contribute to the optimization of the manufacturing process	Exploit the full potential of assembly processes	Ability to criticize and be criticized	Resolve technical problems
6	Flexibility to adjust to different work schedules	Read and interpret drawings (comes in 7th rank) Take measurements with precision instruments (comes in 8th rank)	Designing manufacturing	Ensuring quality control	Embed different practices, such as project, risk and change management, and take into account the constraints associated with these practices	Act quickly in the event of harassment or discrimination

Source: Inventaire des compétences critiques en aérospatiale, rapport et recommandations, Aéro Montréal, 2014.

[9] Subject Matter Expert.

REGROUPING OF OCCUPATIONS AND THEIR EVOLUTION

We covered all aerospace occupations during the interviews. We found that the impact on skills was similar across five broad occupational categories: vocational, technical, engineering, supervisory and management.

The vocational sector includes trades from specialized secondary schools. They are expected to experience major transformations in terms of roles and responsibilities. The increased emphasis on relational and intellectual skills should also change the criteria for selecting future candidates for admission to programs.

Technicians include professionals graduating from colleges. These technicians are taking on a bigger role in product design. Like the professionals, they will need to develop broader skills in terms of relational and intellectual capabilities. Their interests will have to be varied and multidisciplinary to meet the demands of a changing workplace.

Engineering includes scientific trained professionals, including computer engineers. These scientists will have to develop skills in the sharing of knowledge to enable technicians and professionals to make autonomous operational decisions. They will be required to develop knowledge in all fields of engineering to meet the various requirements of system integration and automation. They will have to play a bigger role in business management and they will focus on developing a collaborative or fluid *Product life cycle management*[10].

In terms of supervision, the skills are moving increasingly towards managers able to coach and develop their team. They are becoming continuous improvement leaders and organizational change drivers. In some sectors, they will become team leaders. They could even disappear. This will depend on the quality of the information systems in place. The deployment of real-time information systems and the development of automated planning may well render the role of the supervisor obsolete in the future. The supervisor has a good chance of becoming a virtual system.

The addition of the “management” category is designed to guide company leaders on the skills they need to drive a transition to 4.0. As we have read above, they are the instigators of change. In 2018, too few entrepreneurs are interested in the ongoing transformations in the industry. Among the leaders we met, many told us that they had modified their know-how and their skills to ensure the shift. Some also preferred to leave the field open to more competent managers who are more open to technology.

[10] Definition from Wikipedia**:** An organizational framework and a set of concepts, methods and software tools to create and maintain industrial products throughout their life cycle, from the establishment of product specifications and associated services to the end life, while maintaining operational conditions.

LEVELS OF MASTERING SKILLS

The interview process allowed us to identify the various skills essential to the development and operation of a 4.0 factory. We identified the skills levels required by job category. These levels can be used to guide company managers or training schools in planning skills development plans.

The skills to develop will depend on each company's situation. The digital maturity of the team, the corporate culture, the type of equipment used, the management systems as well as the degree of automation and robotization are among the factors that influence the level of skills development by occupation. Thus, the proposed skill levels are starting points for initiating discussions within a transformational team. Figure 5 presents the levels inspired by Bloom's taxonomy and our experience in developing business skills.

The first level requires a basic mastery of the skill. The person must know what the skill is without mastering it in terms of know-how. At this level, the person is aware. At the second level, the person develops autonomy in mastering and executing the skill but needs coaching and supervision to be successful. At the third level, the person is in full control of the skill and is a recognized expert. An expert person may not be able to train and impart knowledge. This ability defines the fourth level.

Figure 5: Levels of Mastering a Skill

Levels	Descriptions
1	The individual understands the important of the skill. He/she is aware and uses some of it.
2	The individual uses the skill. He/she has a good level of autonomy but needs guidelines.
3	The individual is a recognized expert.
4	The individual is a trainer or coach.

ESSENTIAL SKILLS IN THE ERA OF DIGITIZATION

The identification of skills in the digital age resulted from an analysis of all the interviews. They have been grouped into 7 essential skills to simplify study:

- Technology and the digital world (prerequisites)
- Relational and organizational
- Mathematics and programming
- Data leveraging
- Integration and automation
- Process optimization
- 4.0 business management and co-opetition

Technologies associated with manufacturing production are changing rapidly. These technologies are not fixed in time. They can quickly become obsolete. Thus, we do not recommend focusing skills development on the use of current technologies.

TECHNOLOGY AND THE DIGITAL WORLD (PREREQUISITES)

Undertaking the 4.0 shift requires developing an interest in technology and the digital world. Whether it is to establish a vision or to initiate a transformation without worries, a person's interest in this universe is an essential starting point. *This shift can be made if a good assessment of the level of digital maturity is carried out*[11]*.* It is essential to take stock of the current situation. This report touches on, among other things, the business processes, the technologies used and the skills of the team.

In the aerospace manufacturing sector, many workers are not in contact with technologies. Sometimes, using a computer interface is a big challenge for them. This situation creates resistance to changes. Companies that are developing industrialization 4.0 are mobilizing their employees around the fact that the manufacturing sector will continually be changing. Thus, they are ensuring the development and continuous training of their employees. Some companies have developed a virtual learning centre where the worker is asked to learn about the latest trends in manufacturing technologies. Others have set up a reading library accessible to all. They have appointed people responsible for monitoring innovation and technologies. Training about the digital world is also being offered in companies to stimulate the interest of workers.

Technology and the Digital World (prerequisites)					
Skills	**Assembler, Fitter, Machinist and Mechanic**	**Technician and Methods Agent**	**Engineer**	**Supervisor**	**Leader and Entrepreneur**
Interested in the digital world and in technologies	2	3	3	3	2
Knows how to identify the level of digital maturity	2	2	3	2	2
Knows how to use computer interfaces	2	3	3	3	3
Develops intellectual curiosity	2	3	3	3	3
Develops an interest in continuous education	2	3	3	3	3

[11] Feuille de route de l'Industrie 4.0, Gouvernement du Québec, MESI, 2016.

RELATIONAL AND ORGANIZATIONAL

As we have seen, factory 4.0 emphasizes human capabilities. It forces interactions among people. Increasing the information available on the floor allows workers to take thoughtful initiatives on system improvement opportunities. They need to know how to intelligently communicate their thoughts using a collaborative approach. All departments of the 4.0 company are constantly undergoing change. A department can be both the customer and the internal supplier to another department. A dynamic of influence and search for creative solutions is instilled within the teams. More experienced people become coaches and they share their knowledge in a spirit of openness.

Relational and Organizational					
Skills	**Assembler, Fitter, Machinist and Mechanic**	**Technician and Methods Agent**	**Engineer**	**Supervisor**	**Leader and Entrepreneur**
Ability to synthesize information	2	2	3	3	3
Knows how to share skills	2	3	3	4	4
Judgment and decision-making ability	2	3	3	3	4
Customer-service focus	2	2	3	3	4
Ability to negotiate	2	2	3	3	4
Knows how to anticipate	2	2	3	3	4
Ability to influence (sells his/her ideas)	2	2	3	3	4
Project management ability	2	3	4	4	4
Change management ability	2	2	2	4	3
Demonstrates creativity	2	3	3	2	4
Masters manager-coach approach	2	3	3	4	4
Problem-solving ability	2	3	4	4	3
Masters collaborative intelligence	3	3	4	4	4

MATHEMATICS AND PROGRAMMING

The automation of systems creates programming needs. It's not just about programming a CNC machine, but also programming its interaction with the production line. Defining a decision algorithm to predict the behaviour of the machine allows for a better reading and a better execution of the task to be automated. Understanding what to program requires the development of knowledge in operational mathematics. Visual Basic for Application (VBA) programming is still very present in factory 4.0. Its use depends on the types of internal programming language. In-house application programming skills and user interface design skills are highly sought-after. Historically, this know-how has been relegated to the field of computing. In the digital transformation, the industrial and computer sectors intersect. The technical and scientific trades of the manufacturing sector are developing skills that come from the computer world. The opposite is also true. Meanwhile, skills associated with machine learning are still poorly developed in industrial circles. There is not yet large enough data to allow for the deployment of artificial intelligence. They will probably make a breakthrough with the arrival of predictive maintenance.

Mathematics and Programming					
Skills	**Assembler, Machinist and Mechanic**	**Technician and Methods Agent**	**Engineer**	**Supervisor**	**Leader and Entrepreneur**
Ability to develop decisional algorithms	2	3	4	3	2
Uses advanced Excel functions (VBA)	2	3	4	3	3
Can program internal software programs	1	2	3	1	2
Knows how to use an application programmable interface (API)	2	3	3	2	2
User interface design	1	3	4	1	2
Masters machine learning	2	3	4	2	3

LEVERAGING OF DATA

The connection of equipment and systems as well as process automation generates a large amount of data. These data are to be leveraged. Expertise in data modeling enables information contained in the system to be analysed and designed. For this data analysis to be reliable, it is stored in a database. The harmonious management of databases defines protocols and standardized methods. Operations generate a quantity of information that must be analyzed. Thus, knowing how to use statistics makes it possible to sustain the process of problem solving with conviction. In factory 4.0, decisions are made primarily through data analysis.

Leveraging of Data					
Skills	**Assembler, Machinist and Mechanic**	**Technician and Methods Agent**	**Engineer**	**Supervisor**	**Leader and Entrepreneur**
Ability to model and manage data	2	3	4	1	3
Masters statistics	2	3	4	3	2
Knows how to assemble, harmonize and manage data bases	1	3	4	2	3
Analyses and interprets data science	1	3	4	2	3

INTEGRATION AND AUTOMATION

In industrialization 4.0, systems integration and operations automation are taken into account from the product design stage. Companies with Product Life Management (PLM) must necessarily synchronize their activities with players in the value chain. The goal is to improve productivity. The technical challenges of industrialization are forcing companies to rely on external resources. The search for skills synergy and the efficient operation of the network are essential in the supply chain. *This has the effect of reducing the costs of communication and the development of documents (specifications, plans, invoices...) and accelerates industrialization cycles through collaboration across the network*[12]. Integration cannot be achieved without the control of the IT and enterprise ecosystems that are in place. These ecosystems are the foundation on which the company's operations can build. The implementation of automated systems is a specific skill to be developed. A 4.0 company regularly builds specifications for the connectivity and automation requirements of its equipment.

Depending on the types of customers served by the company, know-how in prototyping products, additive manufacturing and 3D factory simulation are skills required to do business. On a more operational level, skills in robot motion analysis and 3D work instruction design speed up production and ensure greater productivity. Mechatronics is also part of the skills of tomorrow. *Mechatronics is the synergistic and systemic combination of mechanics, electronics, automation and real-time computing. The interest of this area of interdisciplinary engineering is to design powerful automatic systems and to allow the control of complex systems*[13].

Integration and Automation					
Skills	**Assembler, Fitter, Machinist and Mechanic**	**Technician and Methods Agent**	**Engineer and Scientist**	**Supervisor**	**Leader and Entrepreneur**
Masters collaborative PLM management	1	2	4	2	3
Masters IT and enterprise ecosystems	2	3	3	2	3
Knowledge in system automation	2	3	4	2	2
Masters prototyping and additive manufacturing techniques	1	2	4	2	1
Understands how to conduct 3D factory simulations (manufacturing tech. of the future)	1	2	3	1	1
Knows how to analyse robot movements	2	3	4	3	2
Knows how to develop 3D work instructions	2	3	4	2	1
Masters mechatronics	1	2	3	2	1

[12] Désindustrialisation, délocalisations, Report by Lionel Fontagné and Jean-Hervé Lorenzi.
[13] Wikipedia.

PROCESS OPTIMIZATION

To support the business strategy, the 4.0 company needs to have an appropriate alignment of its business processes. These processes are aligned with the needs of customers and reflect the operational excellence of the company. Customer innovation is the lynchpin for improving these processes. To reduce response time and more quickly translate customer expectations into products or services, the most innovative companies will integrate an agile approach into their project management culture. This agile approach requires teams to suggest and test working hypotheses. For some projects, this implies entering an experimental mode.

Process Optimization					
Skills	**Assembler, Fitter, Machinist and Mechanic**	**Technician and Methods Agent**	**Engineer**	**Supervisor**	**Leader and Entrepreneur**
Knows how to develop and manage business processes	2	3	4	3	4
Knowledge in innovation	2	2	4	2	3
Masters agile approach	3	3	4	3	3
Develops a scientific approach: knows how to suggest hypotheses	2	2	4	2	3

4.0 BUSINESS MANAGEMENT AND CO-OPETITION

Knowing how to develop and articulate a strategic vision allows for greater mobilization of all the players who revolve around the company. As we know, the business environment is changing rapidly. Faced with a future that is not always clear, the company that adopts a market vision aligned with the opportunities of 4.0 will stand out from its competition. 4.0 companies will necessarily adopt a business approach based more on co-opetition. Business synergies are to be created to reduce the financial impact of the transformation. This approach to doing business is still not well established in Québec. However, we notice an openness for this type of cooperation between competitors in companies that are very advanced in 4.0.

In 4.0 companies, research and development are well developed. The participation of the university community is solicited. In the digital age, it is common to see academic research projects on the problems and business challenges of companies.

With the increase in equipment connectivity, the addition of technology, and the tide of new data in the workplace, business intelligence is gaining in importance. It is becoming part of corporate governance and no longer solely relegated to the finance department.

4.0 companies want to train their workforce to understand financial statements and know how to make business proposals. Employees in all occupations are destined to become better partners in a company's success. These companies want their workers to understand the reasons behind the changes. They know that a well-informed person is more of an ally than an impediment.

Information virtualization, accelerated data flow and the multiplication of user interfaces require the development of cyber security skills. These skills need to be deployed at different levels across all occupations.

4.0 Business Management and Co-Opetition					
Skills	**Assembler, Fitter, Machinist and Mechanic**	**Technician and Methods Agent**	**Engineer**	**Supervisor**	**Leader and Entrepreneur**
Knows how to develop and articulate a vision	1	1	3	3	4
Knows how to foster co-opetition	1	1	3	2	4
Knowledge in research and development	1	1	3	2	2
Masters business intelligence	1	2	3	3	4
Prepares business proposals	1	2	3	3	4
Knows how to manage cybersecurity	1	2	3	2	2

CONCLUSION

It is difficult to anticipate the future. Many people will say that it is useless to think about it since no one can really determine what is coming. They believe in the system and the business cycle that will eventually reward their patience. In fact, until we have reason to change, we will maintain the status quo. This is only human. We change when we acknowledge the urgency of the situation. To change our habits, we all need to become aware of the situation and identify what we need to change.

In the factory of the future, it is highly likely that machines will, to a large extent, run themselves, the delivery chains will be automatically assembled, and orders will be transformed directly into production information and be found in the production process. Yet, people will remain essential in a world of Industry 4.0 – as creative leaders and thinkers who will use their intelligence to design all the processes and procedures in advance, and who will write software to transmit this information to machines (Siemens, 2017).

In our opinion, it is certain that:

- Ecosystems and industrial platforms are the next path to growth for manufacturing firms. At the very least, they will facilitate business synergies. The availability and costs of technology are making this transformation possible. This change will be rapid and disruptive. The new rules of the competition are being defined.
- Occupations at all levels are in the process of de-specializing. The aerospace worker of tomorrow will have to be interested in all disciplines and technology.
- Starting today, academic institutions need to integrate 4.0 skills to meet future needs.
- Research and support for digital development needs to be stepped up to help the manufacturing industry remain competitive and develop industrial synergies.
- Human resources will need to modernize their internal training process to ensure the transition and retention of knowledge.
- The aviation community will integrate new professions such as computer engineers, product engineers, technology and innovation managers, computer programmers and data scientists.
- This change in the nature of jobs will boost young people's interest in the manufacturing sector, which has been declining significantly over the last 20 years.

Today, too few business leaders are taking the time to meet their customers and other players in the industrial cluster. As in many situations in our modern society, people who should sit at the table and be part of the discussion are not always present. Companies in the industrial cluster remain self-centred. Talk about industrialization 4.0 also seems to be overwhelming. Many view this revolution as a passing fad. It seems that there is still room for awareness and leadership training on the business challenges and impacts of this transformation.

A collaborative business ecosystem needs to be built and it will not happen without a collective mobilization of all the players. The time has come for the decompartmentalization of expertise and for more business synergies. In our opinion, the survival of our jobs and the entire manufacturing industry is at stake. We must nevertheless welcome certain initiatives such as MACH FAB 4.0[14] which proposes a framework for the technological development of companies.

The 4.0 train has already left the station. Some will climb on board; others will watch it pass by.

[14] MACH FAB 4.0 is a tailored support measure designed for SMEs. The goal is to promote the digitization of advanced technologies and advanced manufacturing within participating SMEs.

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About Aéro Montréal's Human Resources Working Group

The Human Resources Working Group is mandated to ensure the planning, coordination and implementation of a concerted action plan to meet the major challenges that the Québec aerospace sector faces with regard to the next generation and workforce and, ultimately, to increase the competitiveness of the industry. The Human Resources Working Group focuses on three priority themes: youth career development, training-employment alignment in the era of Industry 4.0, and knowledge transfer.

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Since 2005, Patrick Bernier has been President of L'Équipe Humania, a firm of 33 human resource management consultants. He has more than 20 years of experience in coaching business leaders and is an expert in deploying strategies for SME growth. In addition to an MBA, Patrick holds a bachelor's degree in Industrial Relations and a certificate in Business Administration from Université Laval. In recent years, he and his team have worked with more than 20 companies in the aeronautics sector. He leads about 10 strategic planning sessions a year. He is particularly interested in technological changes and their impact on the world of work.

SOURCES OF INFORMATION

Documents Consulted

Aerospace 4.0, Hany Moustapha, Professor and Director, AÉROÉTS, École de technologie supérieure, Senior Research Fellow, P&WC, 2016.

Beyond Automation: Digitalization Changes Business Process Design and Execution, Gartner, 2017.

Compétences numériques : Des compétences nécessaires pour soutenir le passage au numérique des PME, CEFRIO, Synthèse, 2016.

Create a Business Manifesto for Digital Workplace Success, Gartner, 2016.

Delivering Business Value with a Digital Workplace, Gartner, 2016.

Digital Business KPIs: Defining and Measuring Success, Gartner 2016.

How Mature Is Your Digital Workplace? Digital Workplace Group, 2016.

Désindustrialisation, délocalisations, Rapport Lionel Fontagné, Jean-Hervé Lorenzi, 2005.

Digital Humanism Is a Key to Digital Success, Gartner, 2015.

Feuille de route de l'Industrie 4.0, Gouvernement du Québec, MESI, 2016.

Four Fundamentals of Workplace Automation, McKinsey & Company, Michael Chui, James Manyika, and Mehdi Miremadi, 2015.

Guide pratique de l'usine du futur, Enjeux et panorama de solutions, Usine du futur, FIM, AIF, 2015.

Industrie 4.0 : Comment caractériser cette quatrième révolution industrielle et ses enjeux? KOHLER Consulting & Coaching, Dorothée KOHLER et Jean-Daniel WEISZ, 2016.

Industry 4.0 — The Ten Things the CIO Needs to Know, Gartner, 2014.

Introducing the Gartner Digital Government Maturity Model, Gartner, 2015.

Inventaire des compétences critiques en aérospatiale, rapport et recommandations, Aéro Montréal, 2014.

Aéro Talents White Paper, Propelling the Talents of Aerospace Towards Industry 4.0, Aéro Montréal, 2016.

Manufacturers Outlook 2017, Growth 4.0, FACTORY, 2017.

Skills 4.0, How CEOs Shape the Future of Work in Asia, The Economist, 2016.

Securing the Future of German Manufacturing Industry, Recommendations for Implementing the Strategic Initiative Industry 4.0, Final Report of the Industry 4.0 Working Group, Acatech, 2013.

The Digital Business Imperative, Forrester, Ted Schadler and Nigel Fenwick, 2017.

2016 Strategic Roadmap for Digital Business Transformation, Gartner, 2016.

Books

Industry X.0: Realizing Digital Value in Industrial Sectors, Accenture, Eric Schaeffer, 2017.

Le guide de la transformation digitale, HUB, Vincent Ducrey, Emmanuel Vivier, 2017.

The Digital Transformation Playbook, Colombia Business School, David L. Rogers, 2016.

The Robotics Revolution, The Next Great Leap in Manufacturing, The Boston Consulting Group, Harold L. Sirkin, Michael Zinser and Justin Ryan Rose, 2015.

Transformation digitale : 5 leviers pour l'entreprise, Tartar Pearson, David Fayon et Michaël Tartar, 2014.

Will Democracy Survive Big Data and Artificial Intelligence? Scientific American, Dirk Helbing, Bruno S. Frey, Gerd Gigerenzer, Ernst Hafen, Michael Hagner, Yvonne Hofstetter, Jeroen van den Hoven, Roberto V. Zicari and Andrej Zwitter, 2017.

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