The Fourth Industrial Revolution « Industry 4.0 »
Aerospace 4.0: Technology and Skills Challenges

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Senior Research Fellow, Pratt & Whitney Canada
July 2017
• Industry 4.0
  - Origin
  - Landscape: Europe - USA – Canada
  - Workforce

• Aerospace 4.0 Technologies

• Skills Challenges
Industry 4.0
INDUSTRY 4.0

Industry 1.0 (1784)  
Steam power – Mechanical production

Industry 2.0 (1870)  
Electric energy – Mass production – Assembly line

Industry 3.0 (1969)  
Electronics – IT – Automation

Industry 4.0 (2011)  
Cyber-Physics-Production-Systems  
Digital-Virtual-Smart

(Deloitte, 2014-15)
Industry 4.0: Nine Technologies (Germany, 2011)
Industry 4.0 (Ref. Aérospatiale 4.0, H. Moustapha, Juillet 2016)

- Big data is the “raw materials and oil” of Industry 4.0 - Connectivity
- Asset knowledge, optimization and management
- Data: sharing, security, reliability, accuracy and variability
- Digital thread: tracking part from cradle to grave
- Artificial Intelligence and data analytics
- Total enterprise and not only manufacturing

FROM:
- Physics to Digital: the “Digital Twin” throughout the product life cycle
- Carbon to Silicon
- Clusters to cloud computing
- Deterministic to probabilistic design
- Experimental to analytical certification
- Mechanical to mechatronics
- Technological to organizational automation
INDUSTRY 4.0

The fourth industrial revolution is beginning to unleash its potential. What do businesses and economies stand to gain? And who will the winners be?

INDUSTRY 4.0 OUTPACING THE GLOBAL ECONOMY

- **Global GDP:** USD 82 trillion
- **Annual growth through 2020:** 2.5%
- **Global Industry 4.0:** USD 13.1 trillion
- **Annual growth through 2020:** nearly 6%

<table>
<thead>
<tr>
<th>RESOURCE PRODUCTIVITY</th>
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</table>
| **USD 30 BILLION** CAN BE SAVED OVER THE NEXT 15 YEARS IF THE USE OF INDUSTRY 4.0 TECHNOLOGIES ENABLES KEROSENE CONSUMPTION TO BE CUT BY 1%.

<table>
<thead>
<tr>
<th>CEO AGENDA</th>
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<tbody>
<tr>
<td>Established at top management level Survey: &quot;Who at your company concerns themselves with Industry 4.0?&quot;</td>
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<thead>
<tr>
<th>GOVERNANCE</th>
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<tr>
<td><strong>41%</strong> OF RESPONDENT COMPANIES HAVE NOT YET APPOINTED SOMEONE WITH OVERALL RESPONSIBILITY FOR INDUSTRY 4.0 TOPICS.</td>
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<table>
<thead>
<tr>
<th>VALUE ADDED</th>
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</table>
| **EUR 78 BILLION** in productivity gains (23%) are feasible in six German industries between now and 2025. Mechanical and plant engineering, electrical engineering and chemicals in particular stand to benefit from Industry 4.0, along with ITC, the auto industry and agriculture.

<table>
<thead>
<tr>
<th>MARKET ANALYSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>15%</strong> INTENSIVELY</td>
</tr>
<tr>
<td>Mechanical engineers</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>GROWTH ENGINE</th>
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</table>
| **Industry 4.0 outpacing the global economy**

<table>
<thead>
<tr>
<th>REGIONAL COMPETITION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial handicap for Europe</strong> Shares of the global ITC market (2013)</td>
</tr>
<tr>
<td><strong>USA 27.1%</strong></td>
</tr>
<tr>
<td><strong>EU 21.3%</strong></td>
</tr>
<tr>
<td><strong>BRIC 18.7%</strong></td>
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<table>
<thead>
<tr>
<th>DIGITAL UNIVERSE</th>
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<tbody>
<tr>
<td><strong>62%</strong> of the world’s data traffic volume in the year 2020 will come from China and India.</td>
</tr>
</tbody>
</table>
Maturity Model for Industry 4.0 (THINK ACT, Nov. 2014)

What must companies do to boost their efficiency, quality and speed as they implement Industry 4.0? How can managers tap their company’s potential? On top of its economic maturity index (see p. 39), Roland Berger Strategy Consultants has now also prepared an analytical index for managers and entrepreneurs. The four most important factors are infrastructure, processes, data traffic and work models. These factors enable us to calculate a company-specific maturity index value highlighting how all departments must pull together. Our study is due out at the beginning of 2015.

### COMPANY ANALYSIS BASED ON ROLAND BERGER'S MATURITY MODEL FOR INDUSTRY 4.0

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>INDICATOR</th>
<th>LEVEL 1 Industry 3.0, basic digital capabilities</th>
<th>LEVEL 2 Maturity, but principles of Industry 4.0 not implemented</th>
<th>LEVEL 3 Industry 4.0 implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFRASTRUCTURE</td>
<td>Sensor technology</td>
<td></td>
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<tr>
<td></td>
<td>Flexible production plant</td>
<td></td>
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<tr>
<td></td>
<td>Use of precision engineering technology</td>
<td></td>
<td></td>
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<tr>
<td>PROCESSES</td>
<td>Production design</td>
<td></td>
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<tr>
<td></td>
<td>Planning and control</td>
<td></td>
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<tr>
<td></td>
<td>Logistics</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DATA</td>
<td>Internal data integration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>External interfaces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WORK MODELS</td>
<td>Flexible work force</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Management models</td>
<td></td>
<td></td>
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</tbody>
</table>
Industry 4.0 and Age of Disruption (Ref. Deloitte, 2014-15)

Industry 4.0: Challenges and solutions for the digital transformation and use of exponential technologies

- Vertical networking (of smart production systems, logistics, services, etc)
- Horizontal integration (of business partners and customers across the globe)
- Through-engineering (throughout the entire product life cycle)
- Acceleration through exponential technologies

Age of disruption: Are Canadian firms prepared?
The five advanced technologies driving disruptive innovation

1. Artificial intelligence (intelligent machines, human know-how)
2. Advanced robotics
3. Networks (big data, internet of things, etc.)
4. Advanced manufacturing (3D printers, nano and bio materials, etc.)
5. Collaborative connected platforms (cloud computing and crowdsourcing)

Internet of Things, People, Data and Services
Internet of Things, Data, Services and People
Artificial Intelligence (AI) is a branch of computer science that refers generally to systems that can think and learn as intelligent humans would.

Machine Learning (ML) is a subset of AI that refers to algorithms that can learn from and make predictions on data.

Deep learning is a branch of machine learning, rebranding of artificial neural networks using layers of nonlinear processing units.

Data Analytics (DA) is related to the processing of data sets in order to build insights with a view to monetizing.

Big Data encompasses software technologies to collect and store massive, heterogeneous and fast changing sets of data in order to bring sense and value (money).

Big Data Analytics combines both big data and DA.
### Periodic Table of AI

<table>
<thead>
<tr>
<th>Dm</th>
<th>Sr</th>
<th>Tm</th>
<th>Ir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data mining</td>
<td>Speech recognition</td>
<td>Text mining</td>
<td>Image recognition</td>
</tr>
<tr>
<td>Se</td>
<td>I</td>
<td>F</td>
<td>Da</td>
</tr>
<tr>
<td>Semantics extraction</td>
<td>Information Fusion</td>
<td>Supervised learning</td>
<td>Descriptive analytics</td>
</tr>
<tr>
<td>Sl</td>
<td>I</td>
<td>U</td>
<td>P</td>
</tr>
<tr>
<td>Supervised learning</td>
<td>Unsupervised learning</td>
<td>Reinforcement learning</td>
<td>Predictive analytics</td>
</tr>
<tr>
<td>Ul</td>
<td>K</td>
<td>Rl</td>
<td>Rb</td>
</tr>
<tr>
<td>Knowledge representation</td>
<td></td>
<td>Rule based</td>
<td>Rule based</td>
</tr>
<tr>
<td>Kr</td>
<td>Cs</td>
<td>Ru</td>
<td>Ps</td>
</tr>
<tr>
<td></td>
<td>Constraint satisfaction</td>
<td>Reasoning under uncertainty</td>
<td>Problem solving</td>
</tr>
<tr>
<td>Mh</td>
<td>Pl</td>
<td>De</td>
<td></td>
</tr>
<tr>
<td>Meta Heuristics</td>
<td>Planning</td>
<td>Decision</td>
<td></td>
</tr>
</tbody>
</table>
Smart – Virtual – Digital: Factory – Supply Chain – Design

Smart Factories:
- Goal: More automation, better control & optimisation of factory processes
- Means: Software, lasers & intelligent devices embedded in machines & factory infrastructure

Factory productivity
- Less waste & energy use
- Increased efficiency
- Fast turnaround
- Better quality

Virtual Factories:
- Goal: To manage supply chains; to create value by integrating products & services
- Means: Software to holistically interconnect & manage distributed factory assets; new business models & value propositions

Supply-chain productivity
- High-value products
- Jobs
- SC transparency
- IPR security
- CO₂ footprint

Digital Factories:
- Goal: To “see” the product before it is produced
- Means: Software for the digital representation & test of products & processes prior to their manufacture & use

Design productivity
- Less design errors
- Better & efficient products
- Less waste + rework
- Faster time-to-market

Automation and robotics leveling the playing field for labor cost From Offshoring to Reshoring
Industry 4.0
Europe
Germany Smart Factory
Birth of Industry 4.0 (2005)
Industry 4.0 Life Cycle (Germany Smart Factory)
Europe Manufacturing Institutes

Germany Smart Factory (2005)

From vision to reality – the SmartFactory\textsuperscript{KL}

- **Launch:** June 2005
- **Legal form:** registered non-profit association
- **Members:** institutions only
- **Governance:** general assembly, executive board
- **Fees:** 12,000 / 3,000 € annual fees
- **Financing:** fees, donations, projects
- **Employees:** currently 20
- **Revenue:** 1 Mio €

The SmartFactory\textsuperscript{KL} is the worldwide biggest and most popular manufacturer independent research and demonstration center for INDUSTRIE 4.0 technologies.
Europe MANUFUTURE and Factories of the Future (FoF)

1. Sustainable manufacturing
(eco-factory, green products, renewable resources, environmental-neutral materials, maintenance of production equipment, re-use of equipment, adaptive & responsive human machine interaction, human-centred production site)

2. High performance manufacturing
(flexible adaptive production equipment, systems & plants, high precision micro-manufacturing machines & systems, tools for production planning & in-situ simulation for open reconfigurable & adaptive manufacturing systems, zero-defect manufacturing)

3. Exploiting new materials through manufacturing
(net-shape manufacturing for engineered metallic & composite materials, new material functionalities through manufacturing processes, renovation & repair, product design using sustainable material process technologies)

4. ICT-enabled intelligent manufacturing
(artificial intelligence, big data, internet of things, cloud computing, crowd sourcing, smart, digital and virtual factory)
Europe MANUFUTURE and Factories of the Future (FoF)
Factory Automation @ 5 TIA Topics
Common features create real added value

Totally Integrated Automation creates real added value in all automation
technical components.

**Benefits:**
- **Consistent, holistic** engineering over the entire product
development and production process.
- **Access** to all the important data occurring in productive
operation – along the entire value chain and across all levels.
- **Integrated communication** based on **international, cross-vendor standards**
that can be flexibly combined.
- **Systematic minimization** of the danger of an internal
or external **attack** on plants and networks.
- **Reliable protection** of personnel, machinery, and environment due to seamless
integration of safety technologies into the **standard automation**.
Siemens Integrated Automation

The Totally Integrated Automation Portfolio
Including ERP Level

Product Lifecycle Management and Enterprise Resource Planning
- Product design
- Product data management
- Production planning
- ERP

Management
- Manufacturing Execution System

Operations
- Totally Integrated Automation Portal
- SCADA System
- Energy Management
- Engineering Framework

Control
- Controller
- HMI
- IPC
- Communication
- Motion Control
- CNC

Field
- Power Supply
- Industrial Identification
- Distributed I/O
- Drive Systems
- Industrial Controls

Added value in all automation tasks

Integrated Engineering
Industrial Data Management
Industrial Communication
Industrial Security
Safety Integrated
Siemens PLM Software

Siemens PLM Software Business Segments

**Product Engineering**
- NX

**Lifecycle Collaboration**
- Teamcenter

**Simulation and Test**
- LMS

**Manufacturing Engineering**
- Tecnomatix

**Specialized Engineering**
- Fibersim, SDE Syncrofit, QPE

**Mainstream Engineering**
- Solid Edge, Femap, CAM Express

**Product Driven Services**
- Advantedge

**Digital Enterprise Realization**
- SIMATIC IT, IBS, Preactor, WinCC

7/10/2017
Industry 4.0

USA
USA National Network for Manufacturing Innovation

NNMI ($1Billion) Vision: “Institutes of manufacturing excellence where some of the most advanced engineering schools and the most innovative manufacturers collaborate on new ideas, technology, methods and processes”

The Institute Design
Creating the space for Industry & Academia to collaborate

White House Report
NNMI Framework Design
January 2013

Partnership: Industry – Academia – Government
Working better, together to create transformational technologies and build new products and industries.
USA National Network for Manufacturing Innovation

Building the Network: Network Status and FY16 Plans

FORTHCOMING FY15

- Topic TBA
- Integrated Photonics
- Smart Mfg.
- Flex. Hybrid Electronics
- DMDII
  - Digital Mfg.
  - Chicago, IL
- America Makes
  - Additive Mfg.
  - Youngstown, OH
- LIFT
  - Light/Modern Metals
  - Detroit, MI
- PowerAmerica
  - Power Electronics
  - Raleigh, NC

Full Network Goal: 45 regional hubs

New Institutes Planned for FY16:

- Open topic competition — addressing “white space” between mission agency topics
- Selected topic competitions supporting Agency mission — using agency authorities and budgets
- FY17-26 – central fund proposed for remaining institutes, via open topic process
USA Manufacturing Institutes

USA DMDII (2015)

Example Institute: Digital Manufacturing

UI LABS/DMDII Facility, Chicago IL
Opening March 2015

94,000 square feet - digital manufacturing manufacturing lab, instructional and collaboration space
A “digital thread” forms the 21st Century Assembly Line for Smart Manufacturing.
Industry 4.0
Canada
Industry 4.0
Started Before 2005

Industry 4.0
Factory or Enterprise?
Pratt & Whitney Canada
Digital Enterprise (2000)

Common Architecture

Customer Demand Fulfillment Process
- Customer Relationship Management (CRM)
- Enterprise Resource Planning (ERP)
- Supply Chain Management (SCM)

Product Development Process
- Product/Process Management
  - Product Creation Simulation
  - 3D model Analysis Drawing NC data Inspection
  - Manufacturing/Maintenance Simulation

Digital Product

As Sold, As Designed, As Planned, As Produced, As Maintained
P&W Advanced Manufacturing Center (2016)
ICEMAN “Intelligent CELls MANufacturing” (2012)

- Closed door machining
- In process measurement
- Dynamic compensation
- Trend monitoring
- Process monitoring
- Process control assurance
- Traceability of quality and process data
- Model, simulate, measure, and optimize
- Predictive maintenance systems
- Machine performance data capture
## Industry 4.0 Factories

<table>
<thead>
<tr>
<th>Region</th>
<th>Initiative</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>Smart Factory (2005)</td>
<td></td>
</tr>
<tr>
<td>Siemens</td>
<td>Digital Factory (2012)</td>
<td></td>
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<tr>
<td>GE</td>
<td>Brilliant Factory (2014)</td>
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<tr>
<td>EU</td>
<td>Factory of the Future (2013)</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>National Network of Manufacturing Innovation (2013)</td>
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</tr>
</tbody>
</table>

### Industry 4.0 Buzz Words:
- Big Data
- Internet of Things
- Data Analytics
- Digital Twin, etc.
Industry 4.0 is not only about **FACTORY**

It is the total **ENTERPRISE**
Industry 4.0 Workforce

Man and Machine in Industry 4.0
How Will Technology Transform the Industrial Workforce Through 2025?

(Ref.: BCG, Sept. 2015)
Industry 4.0 Workforce of Tomorrow (BCG, Sept. 2015)

- Net increase of 350,000 jobs by 2025 for Germany
  - Greater use of robotics and computerization will reduce the number of jobs in assembly and production by 610,000
  - Creation of 960,000 new jobs in IT and industrial data science
- Retrain workforce
- Revamp organization models
- Strategic recruiting and workforce planning
- Education systems to respond to Industry 4.0 needs, provide broader skill sets and close the gap in IT skills

“50% of U.S. workers have a high probability of seeing their jobs automated over the next 20 years” (Oxford University, 2013)
The Workforce of the Future (Ref.: GE, Sept. 2016)

- Innovative business models, process improvements and technological breakthroughs brought into question job sustainability
- Jobs transformed and workers adapted with new advances in automation and technology
- Disruptive technologies created opportunities for jobs that are more strategic
- Over two centuries of innovation, the global economy has provided more and better jobs
- Transition and adjustments have not been painless
- Keeping the status quo to protect the current skillset is suicide for brands in technology and manufacturing
- The need for firms to continuously innovate to win does not equate to a net job loss, but rather a transition to the type of skillsets workers need

Technological Unemployment Theory (Keynes, 1930)
Economizing the use of labor is outrunning the pace at which we can find new uses for labour

Surviving the Technology: Bank Teller vs ATM
Industry 4.0 Workforce Needs (Ref.: BCG, Sept. 2015)

Big-Data-Driven Quality Control:
Algorithms based on historical data identify quality issues and reduce product failures

Robot-Assisted Production:
Flexible humanoid robots perform other operations such as assembly and packaging

Self-Driven Logistics Vehicles:
Fully automated transportation systems navigate intelligently within the factory

Production Line Simulation:
Novel software enables assembly line simulation and optimization

Smart Supply Network:
Monitoring of an entire supply network allows for better supply decisions

From Labor to Capital Intensive
From Offshoring to Reshoring
Industry 4.0 Workforce Needs (Ref.: BCG, Sept. 2015)

Predictive Maintenance:
Remote monitoring of equipment permits repair prior to breakdown

Machines as a Service:
Manufacturers sell a service, including maintenance, rather than a machine

Self-Organizing Production:
Automatically coordinated machines optimize their utilization and output

Additive Manufacturing of Complex Parts:
3D printers create complex parts in one step, making assembly redundant

Augmented Work, Maintenance and Service:
Fourth dimension facilitates operating guidance, remote assistance and documentation

Embedded E-Learning Tools in Real World Situations
Aviation Challenges & Opportunities

- New Markets
- Globalization
- Exchange Rates
- Oil Prices
- Environment

- New Products
- Pricing
- Costs
- Capacity
- Workforce

Plus Collaboration and Partnership
Expected Fleet Growth
30,000 New Aircrafts (2010-2030)

1970-2010: World’s commercial fleets have multiplied by a factor of 6
Reducing Aircraft Operating Cost

POWERPLANT
- Fuel Efficiency
- Weight
- Diameter
- A/C Systems Integration
- Noise & Emissions *
- PPS Cost
- PPS Availability
- Maintenance Cost & Manhours

AIRCRAFT
- TOGW
- Fuel Costs
- Landing Fees
- Navigation Fees
- Airport Taxes
- A/C Acquisition Cost
- Aircraft Availability
- A/C Maintenance Cost

Operating Cost
Manufacturing Technology
Low Cost Game Changers

Turbine Vane – Laser Drilling – Fast EDM

Diffuser – 240 parts to 1

Flank Milling - IBR

Combustor and Fuel Nozzle
Advanced Concepts

Compressor Impeller

Fans (IBR)

Fuel Nozzle

Diffuser Vanes

Hot Streak
Stress & Thermal 3D Analysis

- Optimized for life, weight and cost
- Reduced spin-pit testing
Multi-Disciplinary Optimization
Simultaneous Analyses of a Component

Stress Analysis

Aerodynamic & Cooling Analysis

Dynamic Analysis
Integrated Aircraft Power System Simulation and Optimization

Power Plant - Aircraft Analysis
Fan Bird Strike Tests
“Analytical Certification”

Reduced Development Cost
PW150 Engine - 6000 SHP

All major components analyzed with 3D analytical tools

First 3 Year Program (1990)
Green Engine

Has lowest possible Emission Impact

Has lowest possible Noise Impact

Is manufactured and serviced using Green Processes

Is Material Efficient (Metal Buy-to-fly)

Contains Green Materials

Involves Green Suppliers and Partners

Is designed with Human Factors in mind

Is Energy Efficient during use (Fuel Burn)

Has least possible Factory Impacts

Is Designed for Serviceability, Reusability, Recyclability
“Humans, computers, machines and products collaborate digitally and communicate seamlessly through integrated and optimized processes across the total product value stream within an enterprise, and upstream and downstream of the enterprise”

(Ref. Aérospatiale 4.0, H. Moustapha, Juillet 2016)
Aerospace 4.0™: Addressing the Total Enterprise

Design and Development

Manufacturing and Production

Supply Chain Network

Maintenance and Customer Support

Smart and Digital Enterprise

Simulation
Integration
Optimization

As Sold, As Designed, As Planned, As Produced, As Maintained
Total Enterprise: “Aerospace 4.0 KPI”

1. Design  Multidisciplinary Design Optimization “MDO” (CAD+)
2. Development  Simulation Life Management “SLM”
3. Manufacturing  Multidisciplinary Factory Optimization “MFO” (CAM+)
4. Product  Product Development Process “PDP”
5. Resources  Enterprise Resources Planning “ERP”
6. Customers  Customer Relationship Management “CRM”
7. Suppliers  Supply Chain Management “SCM”
8. Enterprise  Product Lifecycle Management “PLM”

And Workforce
Technology: “Aerospace 4.0 KPI”

1. Simulation
2. System Integration
3. Internet of Things
4. Cloud Computing
5. Cyber Security
6. Augmented Reality
7. Big Data
8. Additive Manufacturing
9. Autonomous Robots
10. Etc.
A Total Enterprise Industry 4.0 Integrated R&D Program

**Design and Development**
- McGill/Mike & ETS/Hany Siemens/Paul ($2M)

**Supply Chain**
- Concordia/Nadia & ETS/Roland Siemens/Andrew

**Manufacturing**
- ETS/Mohammad & Waterloo Siemens/Ali ($3M)

**Production and R&O**
- Concordia/Nadia & ETS/Roland Siemens/Katherine

**Siemens AGT PLM 2020**
Integration and Coordination
- ETS/Hany Siemens/Benoit

**Total: $7M/5 years**
Virtual Engine
“Numerical Test Cell”

- Design System Window
- Design System Data Interface
- Design System Tools Integration
- Visualization
- Grid Generation
- Boundary Conditions
- CATIA (CDM)
- TES
- Test Cells
- 3-D Engine Database
- Engine Validation
- Multiple Designs
- Multi-Physics
- Sizing Tools
- Geometry generation
- 2-D/3-D Analysis Tools
Top Three Manufacturing Technologies

1. Intelligent Manufacturing Systems “IMS” and “MFO”:
   - Multidisciplinary Factory Optimization “MFO”
   - Closed door machining
   - In process measurement
   - Dynamic compensation
   - Trend monitoring
   - Process monitoring
   - Process control assurance
   - Traceability of quality and process data
   - Modeling and simulation of machining
   - Predictive maintenance systems
   - Machine performance data capture
   - Managing “Big data”
   - Etc.
Top Three Manufacturing Technologies

2. Robotics:
   - Precision robotics
   - Human Robot Interaction (HRI)
   - Artificial Intelligence (AI)
   - Collaborative robots (cobots)
   - Robot optimization algorithms
   - Networks integrating intrinsic sensors
   - Etc.

3. Additive Manufacturing (AM):
   - Increasing the number of AM-ready materials
   - Optimally designing, through simulation, AM-specific components to meet functional, economic and environmental requirements of targeted applications
   - Reliably predicting final characteristics of AM-built components through material, process and post-process modeling
   - Modeling material behavior during the AM process
   - Etc.
OUTLINE

• Industry 4.0
  ➢ Origin
  ➢ Landscape: Europe - USA – Canada
  ➢ Workforce

• Aerospace 4.0 Technologies

• Skills Challenges
Specialist vs Generalist

**“SPECIALIST” ROLE**

**What**
We deliver

**Product Quality**
Product meets needs

**Design Reviews**
**Technology Development**
**KPI Management**
**Gated Review**

**“GENERALIST” ROLE**

**How**
We deliver it

**Execution Efficiency**
On time & on cost
Minimum waste

**Lean Engineering**
**Systems Integration**
**Project Management**
**Process Management**
Industry & Workforce Evolution

INDUSTRY NEEDS

FROM

More Specialist
Stability
Expertise → Time Based
Hands on
Limited Data
Face Time Communication

TO

More Generalist
Mobility
Expertise → Tool Based
Simulation
Data Rich
Global Collaboration

WORKFORCE NEEDS
Industry Needs: Agile Engineering

• Business engineers

• Cost, Cost, Cost: Value Engineering

• Process innovation – Lean Enterprise

• Three-dimensional thinking

• Risk definition and management

• Integrate, integrate and integrate

• Systems engineering

• Global competencies
Industry Training Needs
Where Universities can help

Core Technical Education

Design Systems
- Ansys
- CATIA

Generic technical
- Fatigue, damage tolerance
- Basic Controls
- Design of experiments
- Measurement quality
- Uncertainty analysis

Activity Management
- Time
- Contract
- Process
- Project

Communication
- Technical presentations
- Reports
- Prudent business writing

Legal
- Intellectual Property
- Export Control
- Certification Regulations
Industry 4.0 Work Force Needs: Industrial Data Scientists and Robot Coordinators

**Industrial Data Scientist:**
- ICT skills
- Artificial Intelligence (AI)
- User interface design
- Advanced analytics (optimization)
- Root-cause-analysis skills
- Statistical programming

**Robot Coordinator:**
- Oversee robots and respond to malfunction
- Emergency maintenance tasks
- ICT skills

ICT Skills Need to be Integrated in all Technicians, Engineering and Business Curricula
The Digital Leadership

**e-Leadership Qualities**

- Agile Leadership
- Hybrid Skill Development
- Architectural View
- Digital Entrepreneurship
- Value Creator
- Value Protector

**e-Leadership Capabilities**

- Strategy Execution Alignment
- Technology Transformation Alignment
- Competitive Potential Alignment
- Service-Level Alignment

(Li, Liu, Belitski, Ghobadian & O'Reagan, 2016)
Competencies: “Aerospace 4.0™ KPI”

1. Simulation
2. System Integration
3. Data Scientists
4. Artificial Intelligence
5. Advanced Analytics
6. Statistical Programming
7. Digital Leadership
8. Intelligent Manufacturing Systems
9. Robot Coordinator
10. Etc.
Aerospace 4.0: Short Courses

- Introduction to Industry 4.0 and Work Force Needs
- Multidisciplinary Design Optimization “MDO”
- Multidisciplinary Factory Optimization “MFO”
- Machining Simulation
- Intelligent Manufacturing Systems “IMS”
- Product Lifecycle Management “PLM”
- Virtual Testing
- Analytical Certification
- Artificial Intelligence (AI)
- Advanced Analytics
- Data: sharing, security, reliability, accuracy and variability
- Root-Cause-Analysis
- Statistical Programming
- Advanced and Collaborative Robotics
- Additive Manufacturing
- Case Studies
Aerospace: An Emerging Mexican Industry since 2000

260 Factories including Boeing, Bombardier, Honeywell, Safran, etc.

2011 Aerospace Exports: $4.3 Billion  2020 Target: $12 Billion
Western Aerospace Manufacturing Heading to Morocco

Morocco is Quietly Becoming the Next Big Hub in Global Aerospace Manufacturing (Aviation Week, January 2017)

How Morocco Has Become An Aerospace Star and Created the Newest Aerospace Manufacturing Cluster (Aviation Week, Oct. 2016)

Morocco’s Aviation Industry Spreads its Wings (CNN, December, 2015)

Mexico did it – Morocco is doing it « Egypt Can » do it
Establish Egypt as a Middle East Aviation Center for Manufacturing, Maintenance, Research and Development

Hany Moustapha, July 2017