Industrie 4.0: Défis technologiques et futures compétences

Hany Moustapha

Professeur et Directeur, Pole Innovation 4.0

Siemens Chair on Industry 4.0 Technology Integration

Pratt & Whitney Canada Chair on Propulsion System

11 avril, 2019

PÔLE INNOVATION 4.0 HUB

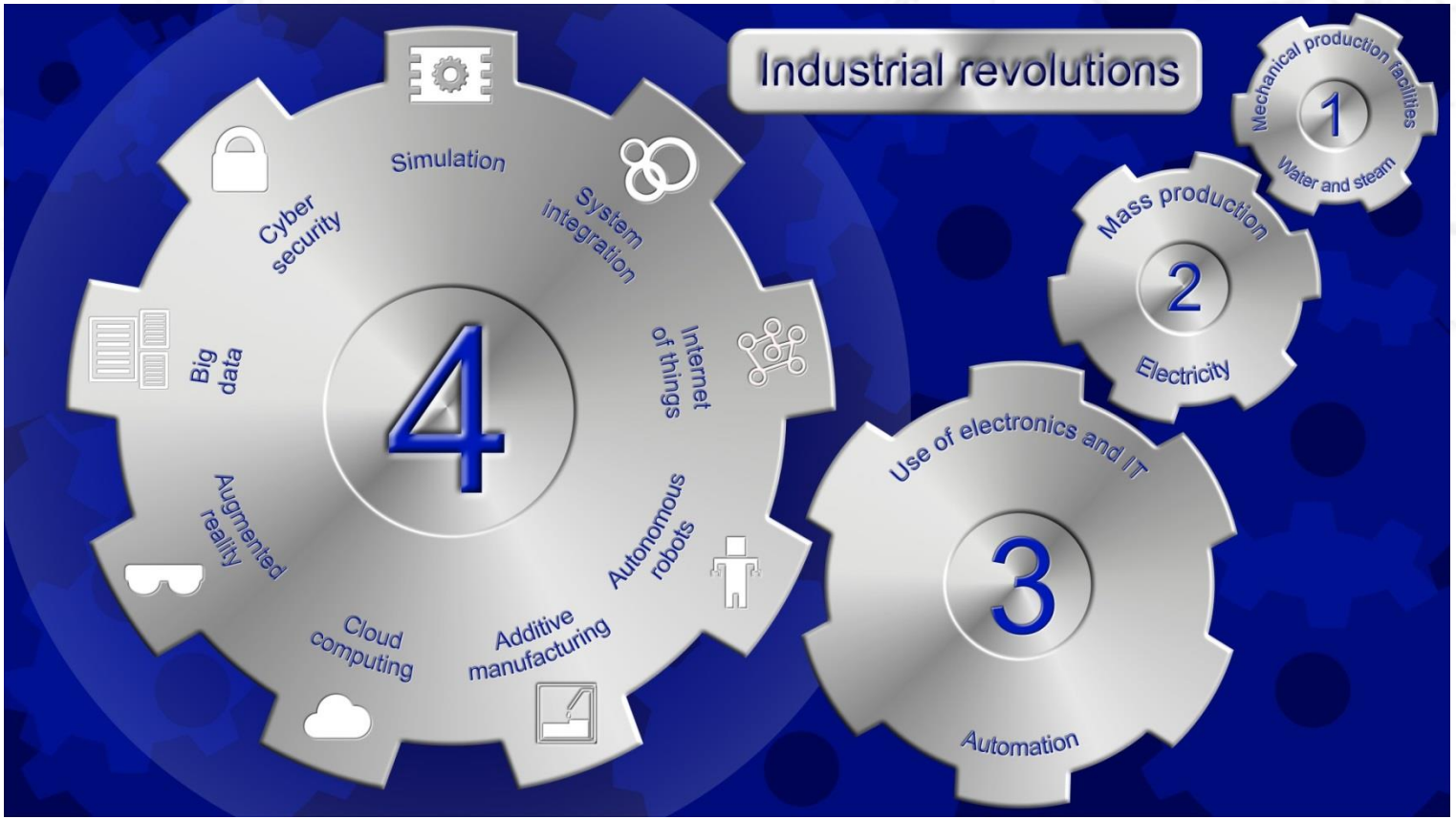
ÉTS Le génie pour l'industrie

OUTLINE

- **Industry 4.0**
  - Origin
  - Landscape: Europe – USA – Canada
  - Workforce – Skills Challenges
- **Aerospace 4.0™ Technologies**
- **Innovation 4.0 Hub – ÉTS Montréal**
- **Innovation 4.0 Network**


Industry 4.0

Industrie 4.0: Neuf Technologies (Allemagne, 2011)



Major Differences w.r.t. Previous Revolutions: Speed - Connectivity - Culture

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)

Tipping Points – Deep Shift Expected to Occur by 2025

(The Fourth Industrial Revolution, K. Schwab, WEF, 2016)

- Implantable mobile phone
- Clothes connected to the internet
- 1 trillion sensors connected to the internet
- The first robotic pharmacist
- The first transplant of a 3D printed liver

- Smart homes through internet: appliances, heating, groceries shopping, etc.
- Reading glasses connected to the internet
- The first human with fully artificial memory implanted in the brain
- The first 3D printed car in production
- Driverless cars
- Etc.

"Industry 4.0: Velocity – Breadth and Depth (radical changes) – Systems impact (transformation of the whole system)"

When Artificial Intelligence becomes the Mother of All Technologies (Roland Berger, 2018)

In less than two decades, **three waves of technological disruption** have swept across our economies and societies:

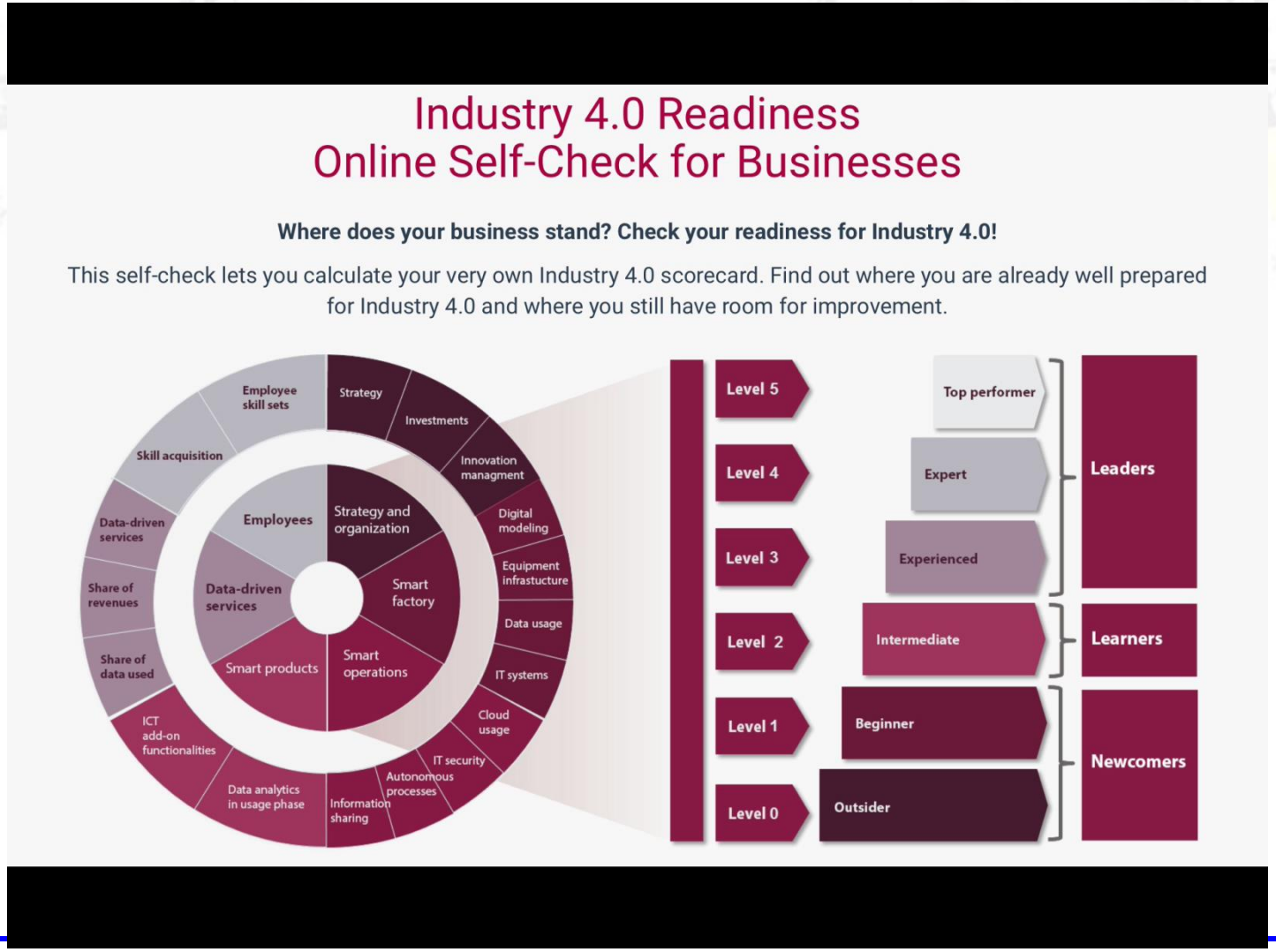
1. **Hardware,** with IBM, Apple and Intel as the big winners
2. **Software** and operating systems, which Microsoft largely pioneered
3. **Smartphones** or Apple's iPhones that have since become the remote control of our lives

Today, we are about to enter a **fourth wave**, which will combine existing **hardware and software, fueled by powerful AI**

Gradually moving from deep learning technologies to machine reasoning and genetic algorithms, there will also be progress in the development of new forms of AI solutions and technology.

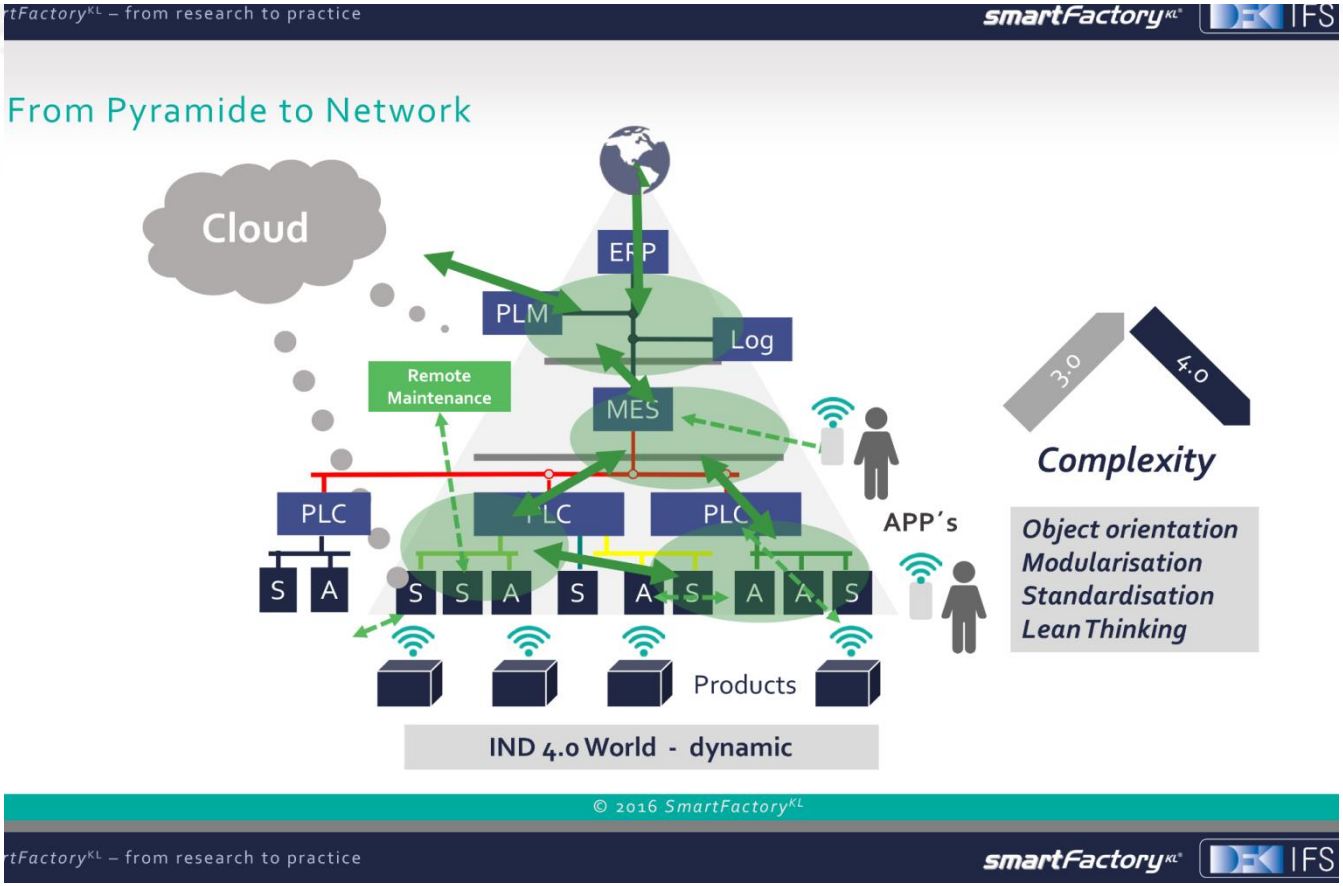
Personal Portable AI Devices which will be Heavily Disruptive

Industry 4.0 Readiness (VDMA, Germany , 2016)



Industry 4.0
Europe

Germany Smart Factory
Birth of Industry 4.0 (Kaiserslautern, 2005)



Europe MANUFUTURE and Factories of the Future (FoF)

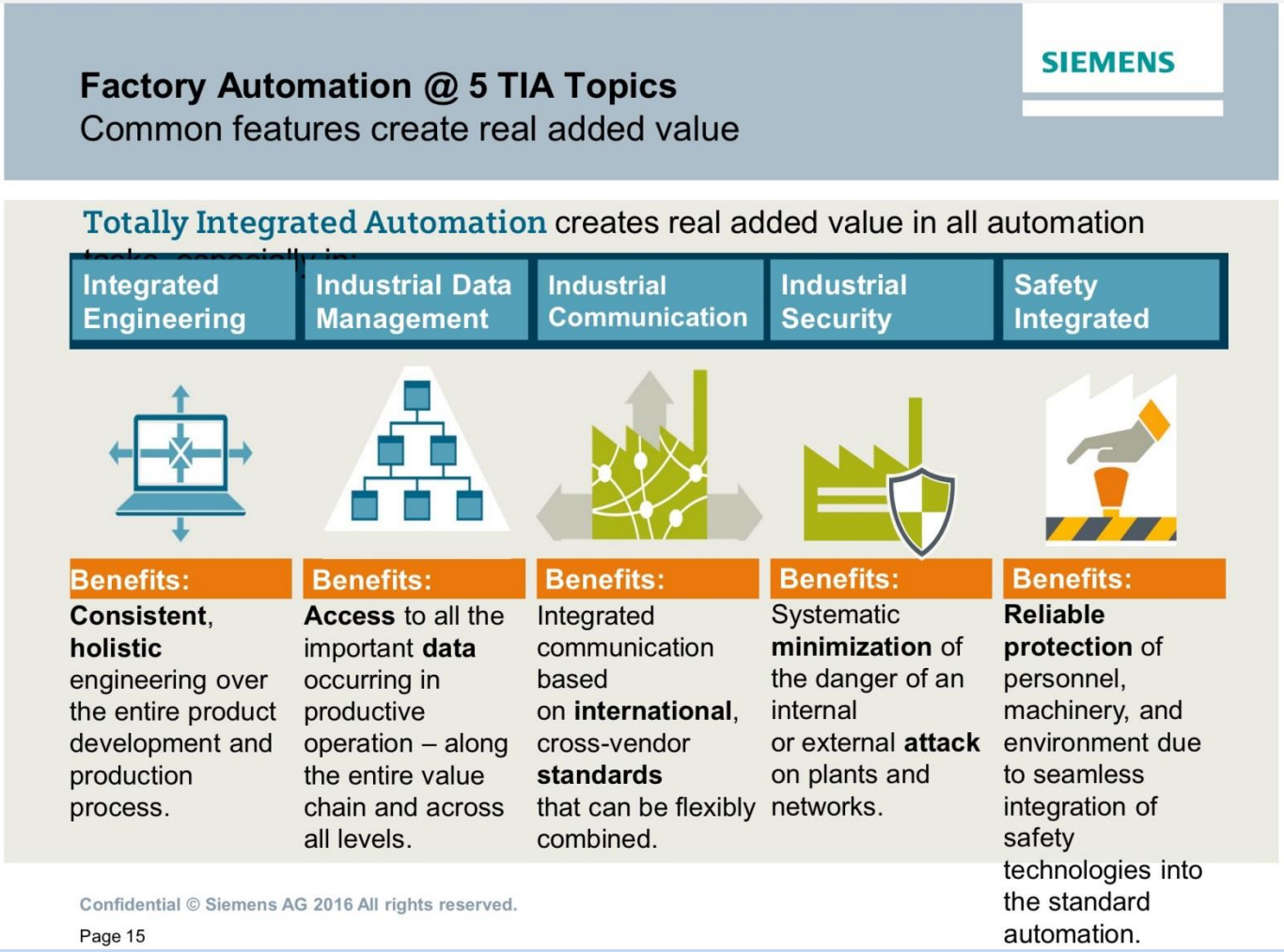
1. Sustainable manufacturing
(eco-factory, green products, renewable resources, environmental-neutral materials, maintenance of production equipment, re-use of equipment, adaptive & responsive human machine interaction, human-centred production site)

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)

Siemens "Digital Factory" Integrated Automation

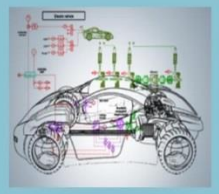


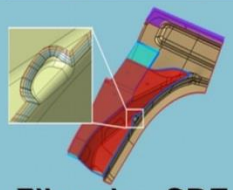
$10B since 2007 on Software - $1.2B R&D on Digitization (2017)
25,000 Software Engineers

Siemens PLM Software

SIEMENS

Siemens PLM Software Business Segments

Product Engineering	Lifecycle Collaboration	Simulation and Test	Manufacturing Engineering
			
NX	Teamcenter	LMS	Tecnomatix

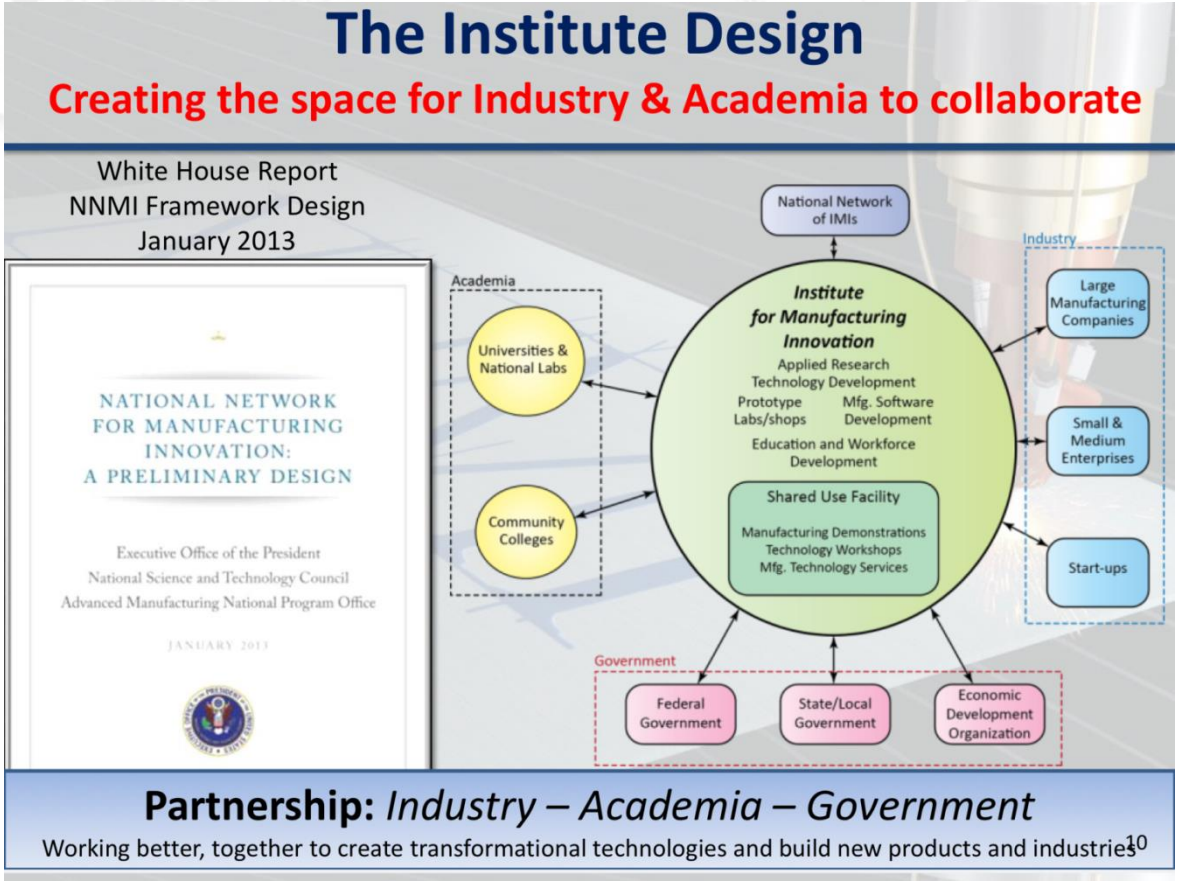
Specialized Engineering	Mainstream Engineering	Product Driven Services	Digital Enterprise Realization
			
Fibersim, SDE Syncrofit, QPE	Solid Edge, Femap, CAM Express	Advantedge	SIMATIC IT, IBS, Preactor, WinCC

MindSphere: Cloud Based Open IoT Operating System

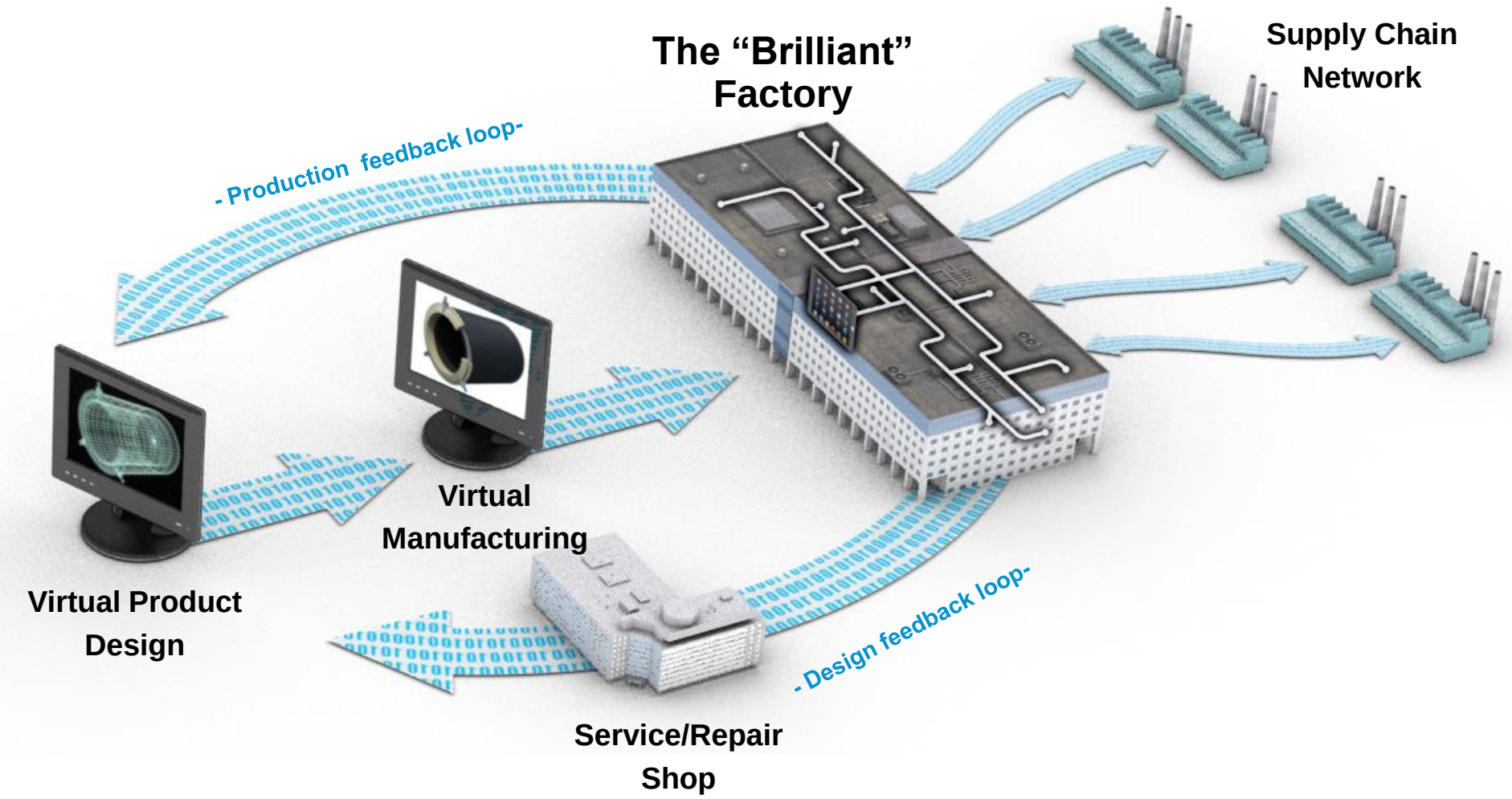
Industry 4.0
USA - Japan

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"



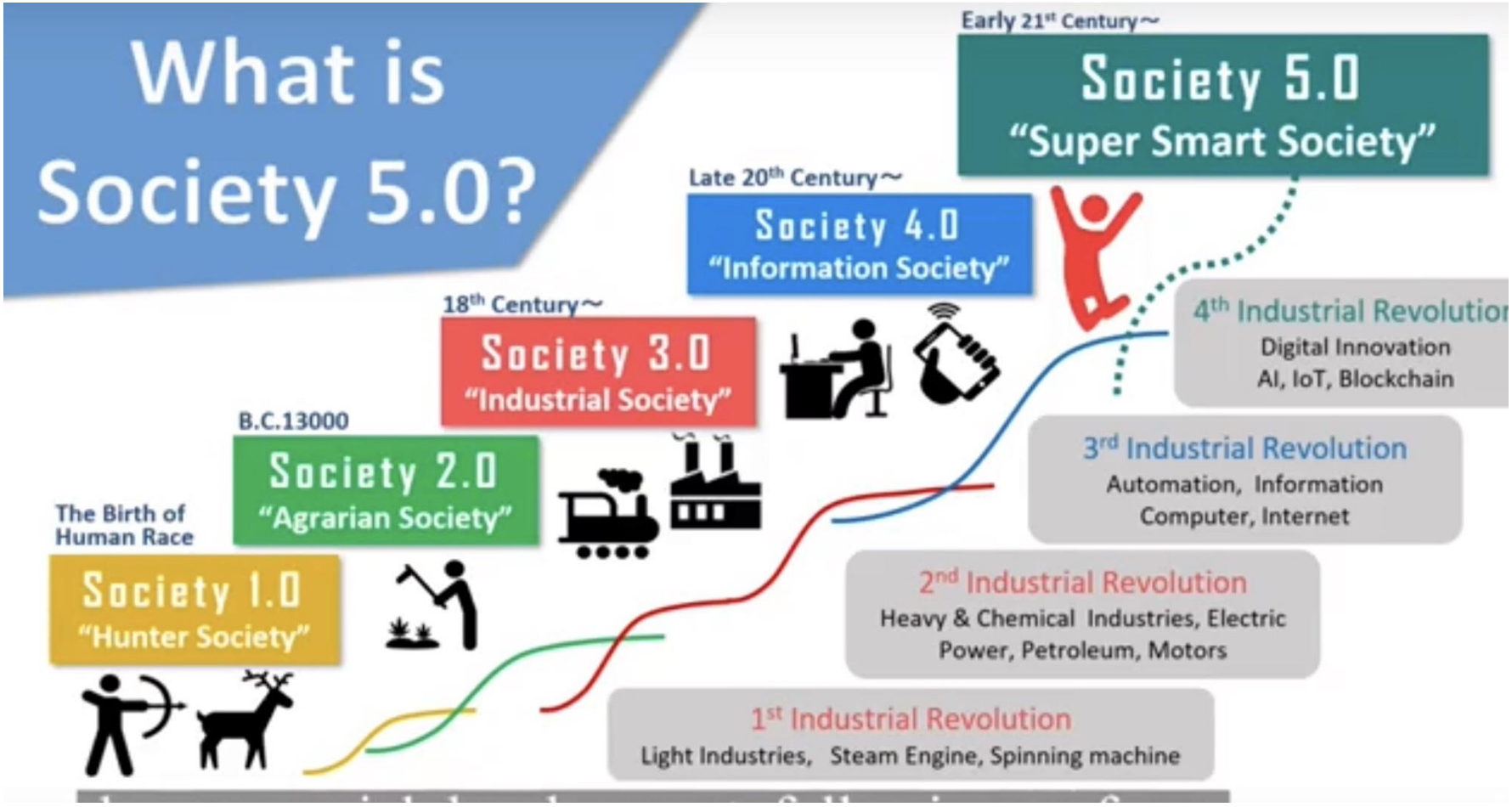
GE Brilliant Factory



A "digital thread" forms the 21st Century Assembly Line for Smart Manufacturing

imagination at work

Society 5.0



Japan (2017)

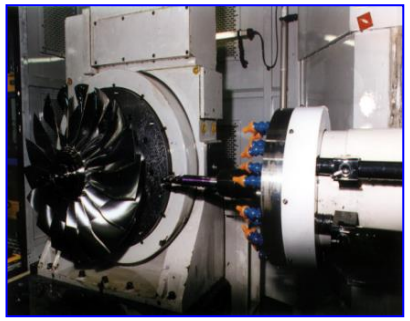
Industry 4.0 Canada

Industrie 4.0 a

Commencé avant 2011

Industrie 4.0:

Usine ou Entreprise ?



Pratt & Whitney Canada Digital Enterprise

*(H. Moustapha, P&WC, 2000: **Industry 4.0 started before 2011**)*

Common Architecture

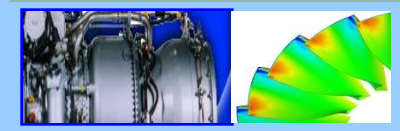
Customer Demand Fulfillment Process

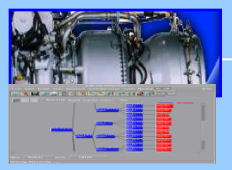
- Customer Relationship Management (CRM)
- Enterprise Resource Planning (ERP)
- Supply Chain Management (SCM)

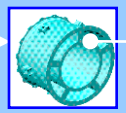
Product Development Process

Product/Process Management

Product Creation Simulation







3D model
Analysis
Drawing
NC data
Inspection

Digital Product

Manufacturing /Maintenance Simulation

As Sold, As Designed, As Planned, As Produced, As Maintained

The word **“Digital Enterprise”** is back again in 2019

Digital Enterprise – Thinking industry further!

Hannover Messe 2019 | 1. April 2019
Klaus Helmrich, Mitglied des Vorstands der Siemens AG und CEO Digital Industries

Industry 4.0 Characteristics *(H. Moustapha, June 2016)*

- **Artificial Intelligence** "AI" and data analytics: knowledge & decision making
- **Big "Good" data** is the "raw materials and oil" of Industry 4.0 and AI
- **Data**: sharing, security, reliability and variability: **Who owns the data ?**
- **Asset**: knowledge, optimization and management
- **Digital thread**: tracking part from cradle to grave **"Real Time Connectivity"**
- **"Connecting the Unconnected"**
- **End to end digital data continuity**
- **Digital Operations Transformation**

- **Digitization**: Technology enabler - **"Digital Disruptive"**
- **Total enterprise** and not only manufacturing

Industry 4.0 Characteristics *(H. Moustapha, June 2016)*

FROM:

- Physical to Digital: the **"Digital Twin"**

  (Digital Twin existed for design: Digital to Physical)

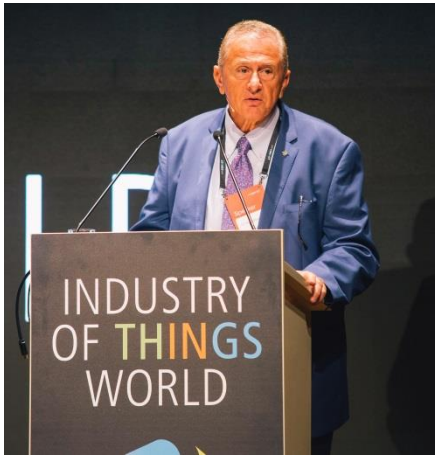
- Carbon to Silicon
- **Assets to Services** (Uber and Airbnb)
- Clusters to **cloud computing**
- Mechanical to mechatronics
- Technological to **organizational automation**

Shared Economy – Electronics Platforms: Uber and Airbnb

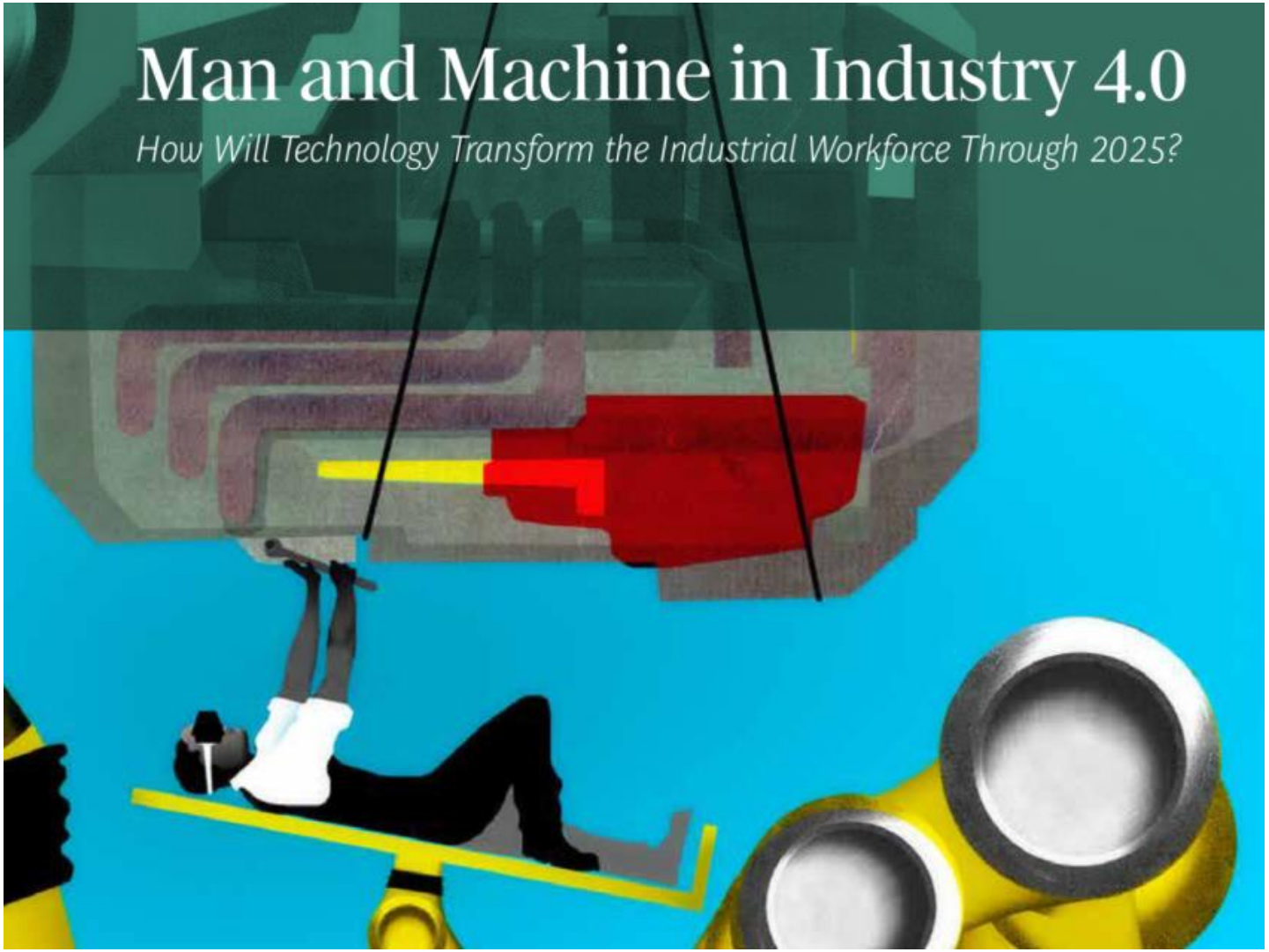
Démystifier l'Industrie 4.0

"Les humains, les ordinateurs, les machines et les produits collaborent numériquement et communiquent de façon transparente grâce à des processus intégrés et optimisés à tous les niveaux de la chaîne de valeur du produit, à la fois en amont et en aval dans l'entreprise"

(Ref. Aérospatiale 4.0, H. Moustapha, Juillet 2016)



Industry 4.0 Workforce



(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

"Some Jobs will Disappear: Protect Workforce and Not Jobs"

"The Future: Focus on Tasks and not Jobs"

The Workforce of the Future

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

- 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
- Keeping the status quo to protect the current skillset is suicide for brands in technology and manufacturing
- Some jobs will disappear: Protect workforce and not jobs

Surviving the Technology:
Bank Teller vs ATM - Air Travel vs Skype Meetings

Industry 4.0: Re-Engineering University Curricula

Big-Data-Driven Quality Control

Robot-Assisted Production

Self-Driven Logistics Vehicles

Production Line Simulation

Smart Supply Network

Predictive Maintenance

Machines as a Service

Self-Organizing Production

Additive Manufacturing

Augmented Maintenance & Service

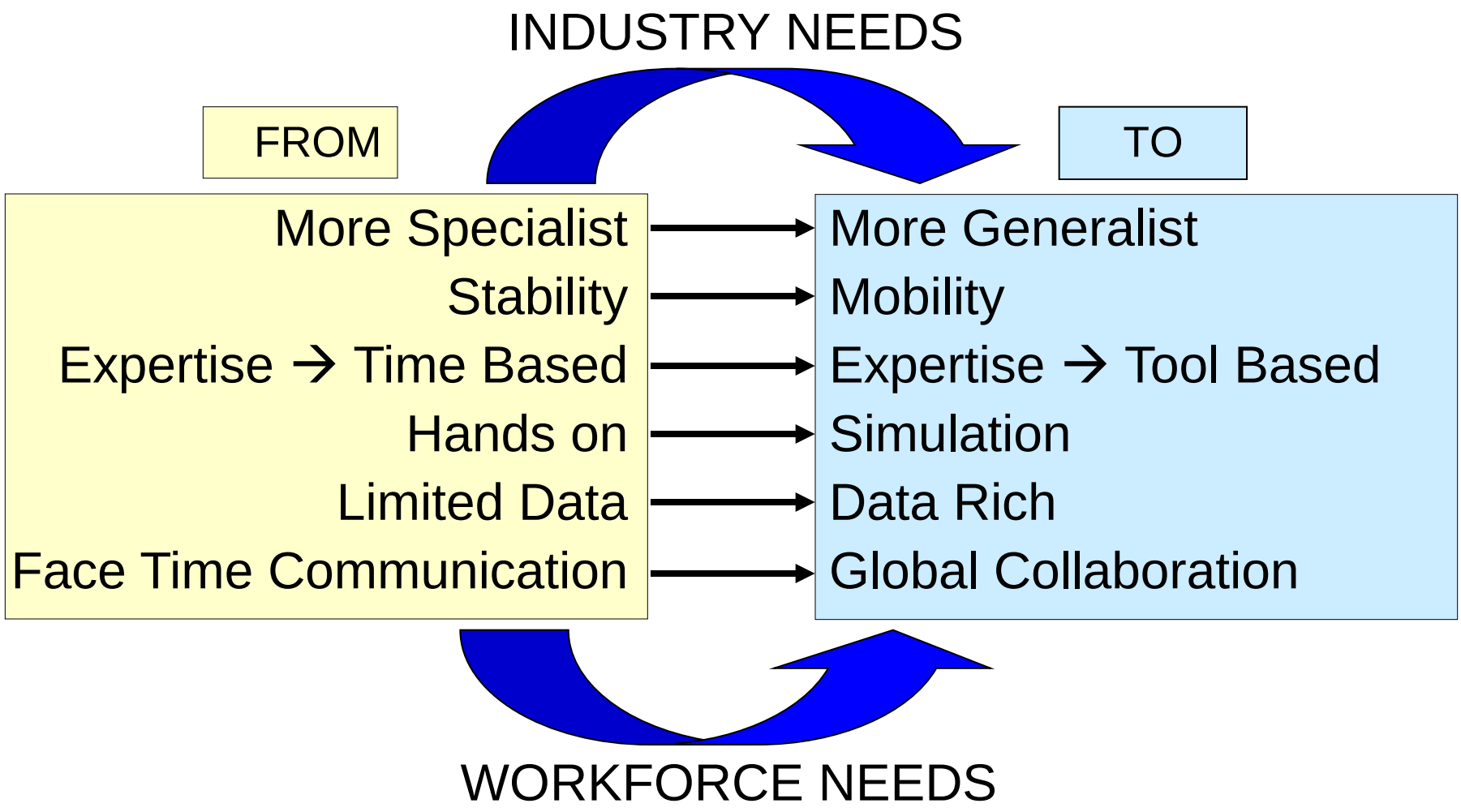
Industrial Data Scientist

- Manufacturing and production knowledge
- ICT skills
- Artificial Intelligence (AI)
- User interface design
- Advanced analytics
- Root-cause-analysis skills
- Statistical programming

“Digital Native”

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

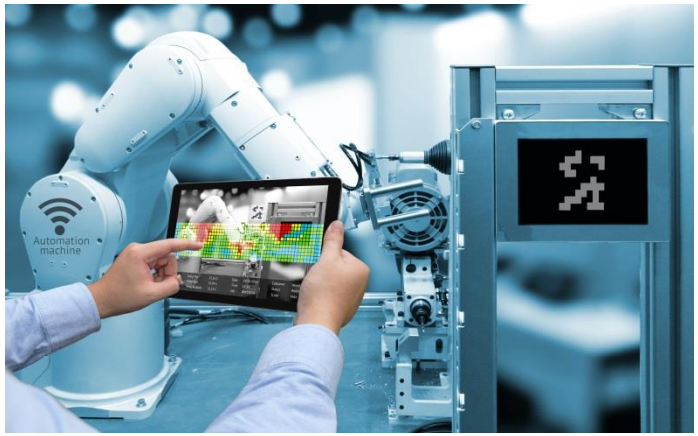
Industry 4.0 Workforce Needs
“Le génie connecté”



Aéro Competencies 4.0

7 grandes compétences essentielles à l'aire de la digitalisation

- Technologie et monde digital (prérequis)
- Relationnelle et organisationnelle
- Intégration et automatisation
- Optimisation des processus
- Mathématique et programmation
- Valorisation des données
- Gestion des affaires



Projet AéroMontréal: Définir les Compétences 4.0

Intégration et Automatisation

Compétences	Assembleur, monteur machiniste et mécanicien	Technicien & agent méthode	Ingénieur et scientifique	Superviseur	Dirigeant & entrepreneur
Maîtriser la gestion du PLM collaboratif	1	2	3	2	2
Maîtriser les écosystèmes informatiques et d'entreprises	2	3	3	2	2
Monter des cahiers charge sur les requis de connectivité et d'automatisation des équipements	2	2	3	2	2
Savoir faire en automatisation des systèmes	2	2	3	2	2
Maîtriser les techniques de prototypage et de fabrication additive	1	2	3	1	1
Maîtriser l'électromécanique	1	2	3	1	1
Savoir analyser les mouvements d'un robot	2	3	3	3	1
Savoir développer des instructions de travail en 3D	2	3	3	3	1
Apprendre à faire des simulations d'usine en 3D (Tech. fabrication du futur)	1	2	3	1	1

Entrevues réalisées chez 11 entreprises
Guide des compétences (Juin 2018)

Aerospace 4.0™

AÉROÉTS

Engineering for Aerospace 4.0

Aérospatiale 4.0™: An Integrated Research and Education Program to Address Industry 4.0

(created in May 2016)

AÉROÉTS
Engineering for Aerospace 4.0

Aerospace 4.0™ :

Towards a Smart and Digital Enterprise

After two years of analysis and discussion with the industry, AÉROÉTS launched in May 2016 a new **integrated research and education program: Aerospace 4.0.**

The objective of this program is to mobilize ÉTS experts, who have been working since 2008 on various technologies related to **Industry 4.0**, in order to address the needs of the aerospace industry in terms of **research, development, education and training.**

Research and Development

This focus area aims to leverage the strengths of ÉTS, in partnership with other academic and research institutions, to carry out R&D projects on Industry 4.0 technologies for the aerospace sector.

Examples of majors research themes identified:

- Robotics and additive manufacturing
- Intelligent Manufacturing Systems (IMS) and Multidisciplinary Factory Optimization (MFO)
- Multidisciplinary Design Optimization (MDO) and product development simulation
- Smart supply chain and logistics – Product Lifecycle Management (PLM)
- Advanced predictive maintenance systems
- Etc.

A digital-virtual enterprise laboratory will be created, including all the simulation tools required to support our industrial partners.

What is "Industry 4.0"?

Industry 4.0 is characterized by automation and digitization, knowledge, optimization and management of assets, reliability, accuracy, variability, sharing and security of data, tracking parts from cradle to grave (the "Digital Thread"), data analytics and Artificial Intelligence (AI). Big data is the "raw material" of Industry 4.0. It is the transformation from: the physical to the digital (the "Digital Twin"), carbon to silicon, clusters to cloud computing, deterministic to probabilistic design and experimental to analytical certification.

It is the democratization of technology, where humans, computers, machines and products communicate and collaborate. This transformation will touch every organization in a company affecting the Product Value Stream: marketing, engineering design, development testing, manufacturing, supply chain, customer support, service center, etc. It is a transformation from the traditional silo-centric optimized business unit to a value-stream optimized enterprise.

(Ref.: Aerospace 4.0, H. Moustapha, July 2016, aeroets.etsmtl.ca)

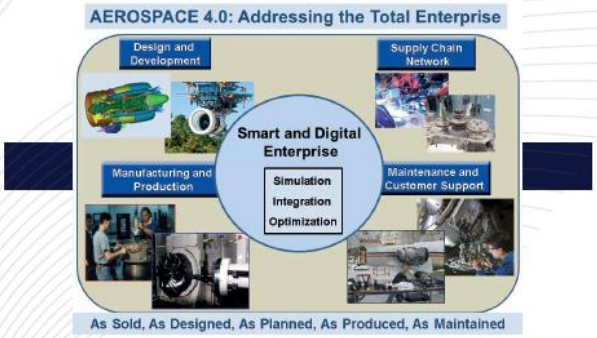
ÉTS
Engineering for Industry

Courses, workshops and seminars on Industry 4.0

In collaboration with our academic and industrial partners, AÉROÉTS will offer new training courses to address the challenges of Industry 4.0 for the aerospace sector. Short courses of one to three days are planned on the theme of the **"Smart and Digital Enterprise".** These courses will include the following topics:

- Artificial Intelligence
- Big data: reliability, variability, sharing and security
- Collaborative robotics
- Additive manufacturing
- Modeling and simulation of machining processes
- Multidisciplinary design and optimization
- Virtual development testing
- Etc.

Please consult our website for dates and venues of future courses.



For more information contact:

Hany Moustapha, Ph.D., C.Q.
Fellow ASME, CASI, CSME & CAE
Professor and Director, AÉROÉTS
École de technologie supérieure
Pratt & Whitney Canada Senior Research Fellow

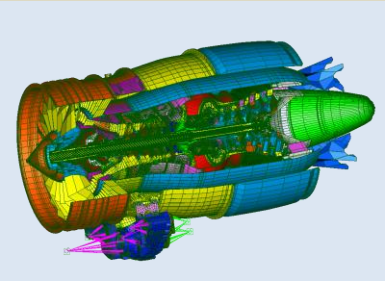
AÉROÉTS
Engineering for Aerospace 4.0

hany.moustapha@etsmtl.ca
514 396-8436
aeroets.etsmtl.ca

ÉTS
Engineering for Industry

Aérospatiale 4.0™: Cibler la totalité de l'entreprise

Conception et développement

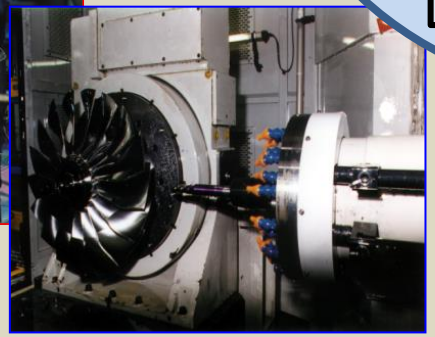


Chaîne d'approvisionnement

Entreprise intelligente et numérique

Simulation
Intégration
Automatisation
Digitilisation
Optimisation

Fabrication et production

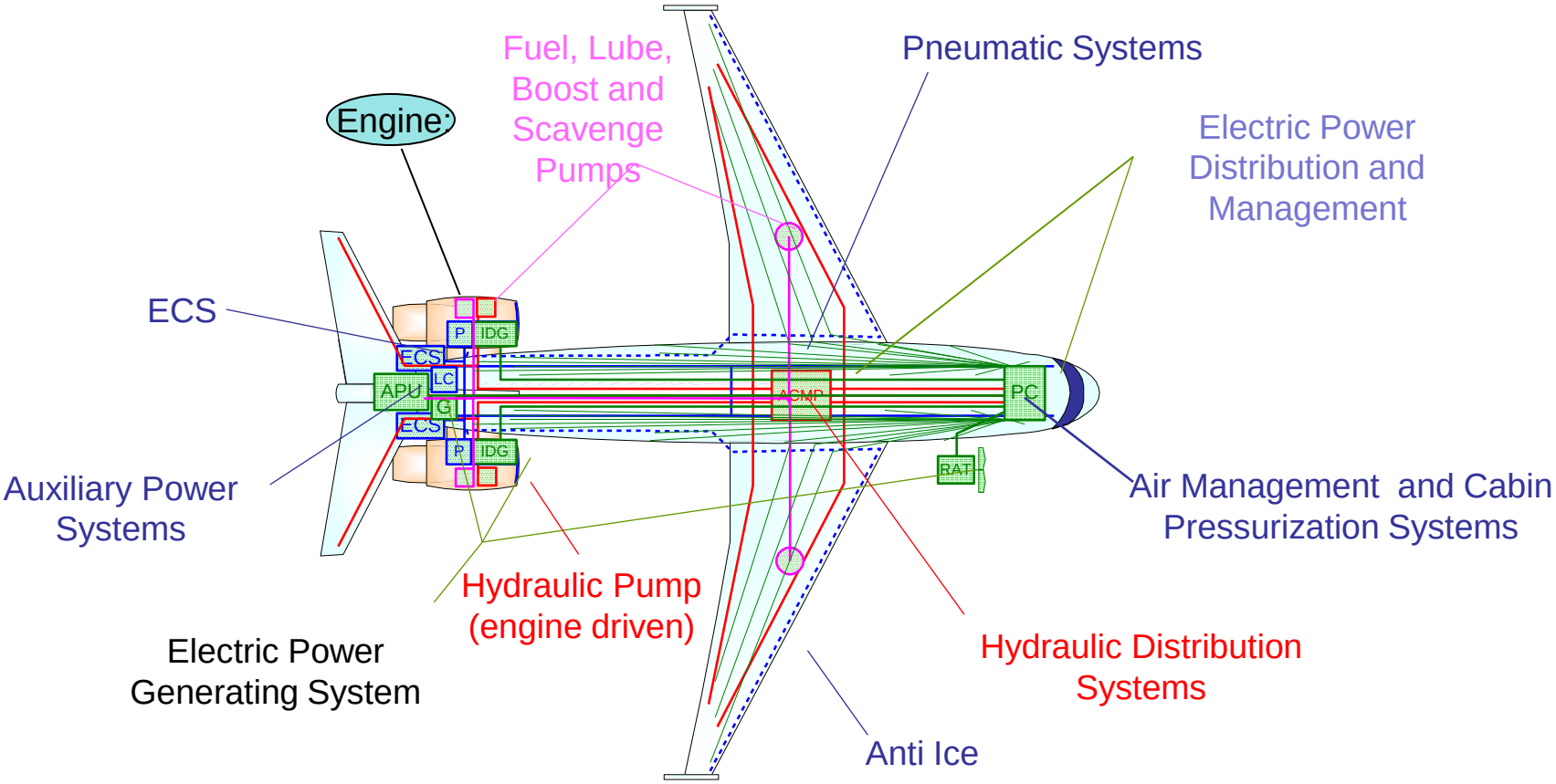


Maintenance et service à la clientèle

Tel que vendu, tel que planifié, tel que produit et tel qu'entretenu

Integrated Aircraft Power Systems Simulation and Optimization

Propulsion Systems | Electrical Systems | Fuel Systems | Hydraulics Systems | Pneumatic Systems



Big Data Analytics - Connecting Flying Objects (Aircrafts)

Top Three Manufacturing Technologies

1. Intelligent Manufacturing Systems “IMS”

- Closed door machining
- Dynamic compensation
- Trend and process monitoring
- Modeling and simulation of machining
- Predictive maintenance systems

2. Robotics

- Precision robotics
- Human Robot Interaction (HRI)
- Collaborative robots (Cobots)

3. Additive Manufacturing (AM)

- Increasing the number of AM-ready materials
- Optimally designing, through simulation, AM-specific
- Reliably predicting final characteristics of AM-built components

NUMÉRIX (an ÉTS-PLM Research Lab. since 2013)

Infrastructure de recherche

Logiciels utilisés

- **PLM** – Product Lifecycle Management
- **CAO** – Conception assistée par ordinateur
- **LCA** – Life Cycle Analysis
- **ERP/SCM** - Enterprise Resource Planning / Supply Chain Management
- **APS** – Advanced planning and scheduling
- **MES** – Manufacturing Execution systems
- **WMS** – Warehouse Management System
- **CRM** – Customer Relations Management
- **BI** – Business Intelligence
- **EAM** – Enterprise Asset Management

1 Amin Chaabane
2 Claude Olivier
3 James Lapalme
4 Louis Rivet
5 Marc Paquet
6 Michaël Gardoni
7 Michel Rioux
8 Mustapha Ouhimmou
9 Roland Maranzana
10 Yvan Beauregard

Concentation entreprise numérique

ÉTS
Le génie pour l'industrie

Total Enterprise: "Aerospace 4.0 KPI"

AÉROÉTS
Le génie pour l'aérospatiale 4.0

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

PÔLE INNOVATION 4.0 HUB

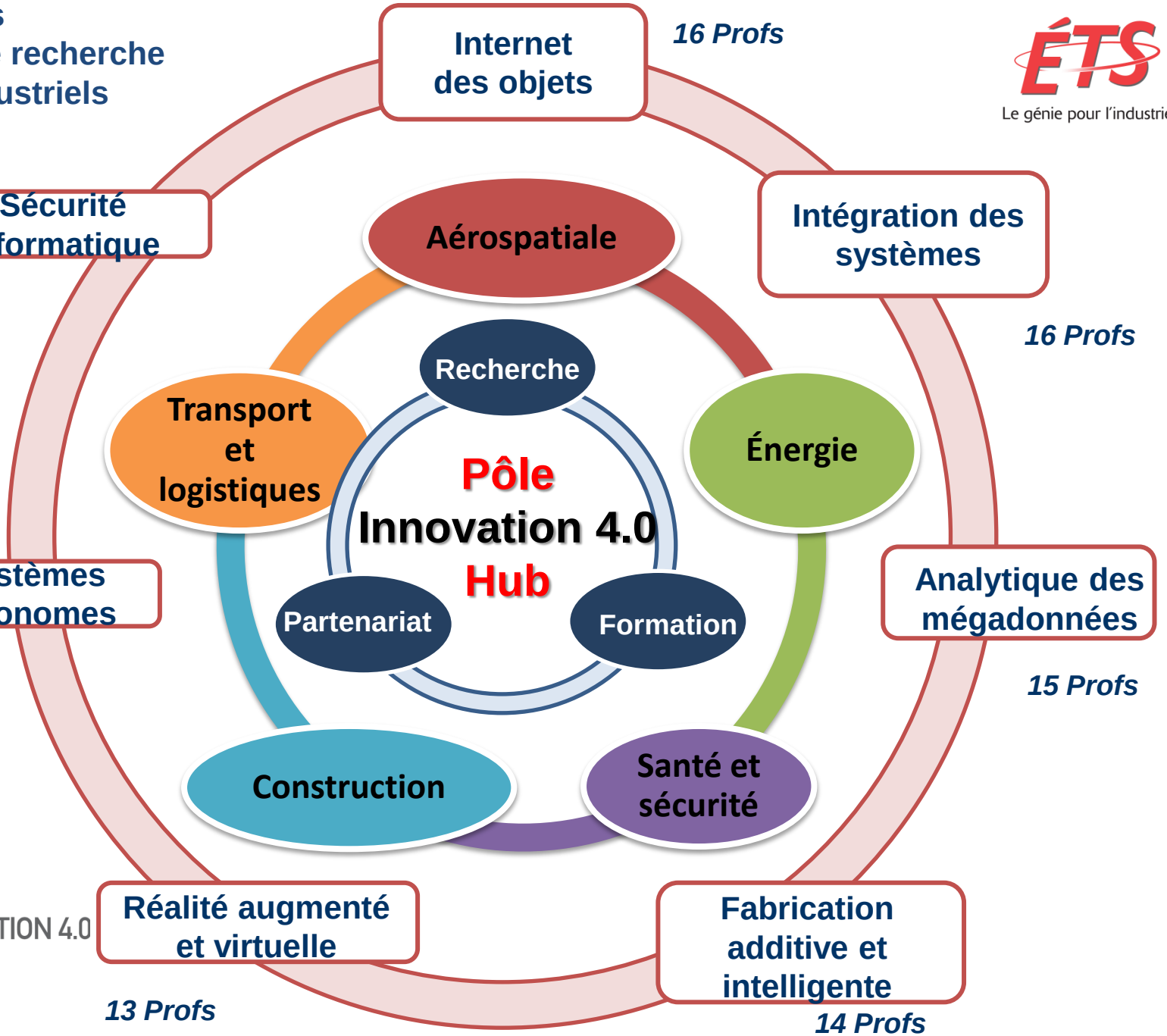
Créé Nov. 2018

MISSION

Le « **Pôle Innovation 4.0** », en collaboration avec les départements et services concernés, représente, promeut et intègre les activités d'enseignement et de recherche de l'ÉTS touchant les technologies de l'Industrie 4.0.

Le « **Pôle Innovation 4.0** » favorise la mobilisation et l'échange entre les professeurs, chercheurs et étudiants intéressés par ce domaine, contribue au développement de partenariats stratégiques au niveau national et international et facilite l'accès au financement.

54 Professeurs
7 Domaines de recherche
5 Secteurs industriels



ÉTS
Le génie pour l'industrie

PÔLE INNOVATION 4.0 HUB

Créé Nov. 2018

PÔLE INNOVATION 4.0 HUB

Plan Formation 2019

- Faire croître le laboratoire d'enseignement "NUMÉRIX" d'entreprise virtuelle en intégrant de nouveaux logiciels de simulation
- Appuyer la concentration "Entreprise numérique" et développer une "Maîtrise en Innovation 4.0"
- "Digitalisation de l'industrie manufacturière ": demande de financement pour la formation (programme FONCER)
- "Conférence-midi" mensuelles : « Les Mardi 4.0 »
- "École d'été 4.0" consacrée à l'Industrie 4.0

ÉTS Le génie pour l'industrie

PÔLE INNOVATION 4.0 HUB

Plan Recherche et Partenariats 2019

- Appuyer la Chaire Siemens 4.0 ($5M/5ans)

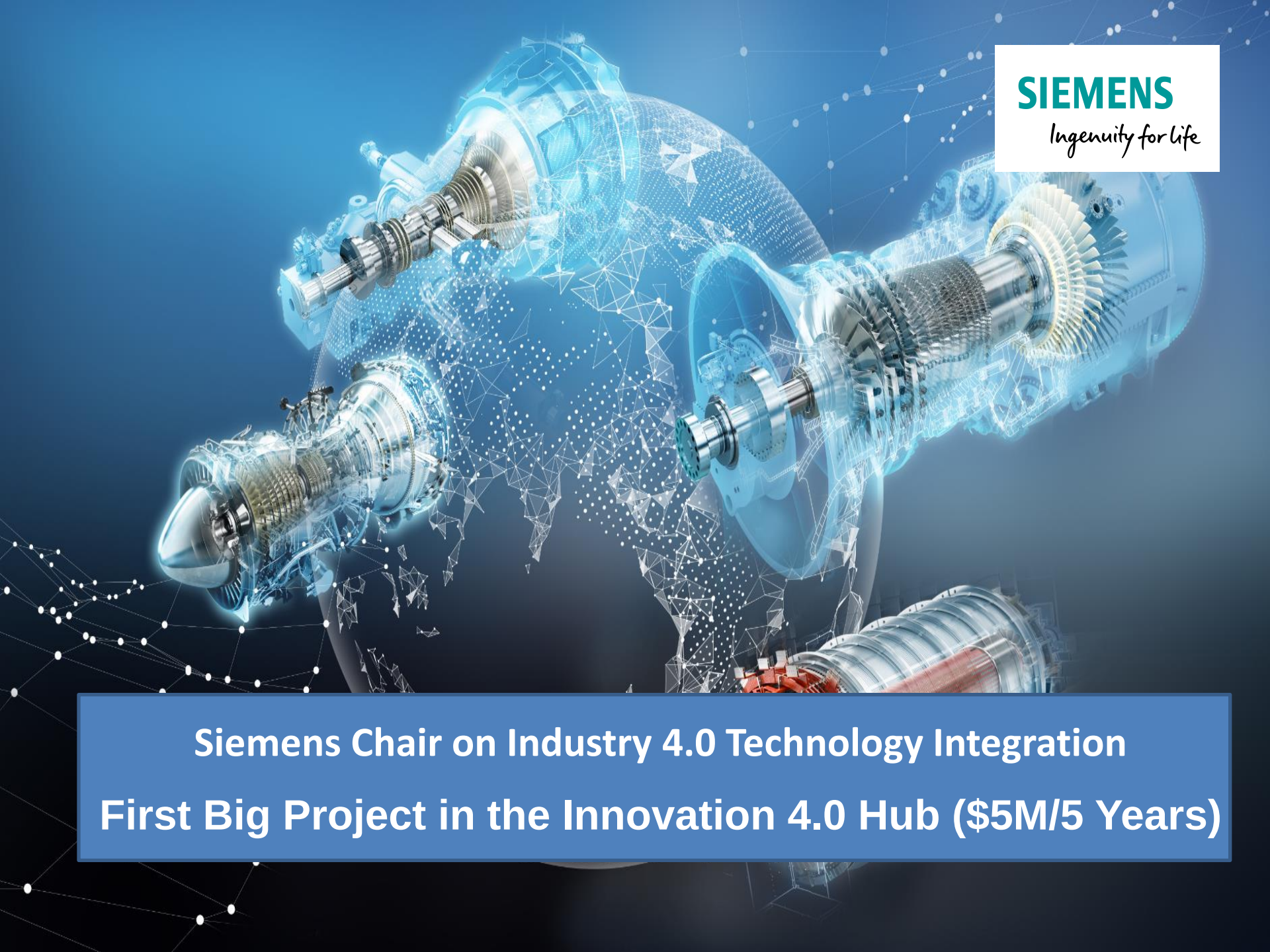
- Faire des démarches pour obtenir une Chaire en innovation sur la transformation numérique des PME ($4M/5ans) et une Chaire CRC 4.0 ($1.4M/7ans)

- Supporter la Cohorte 4.0 du CENTECH

Réseau Innovation 4.0 Network

- Partenariat avec le “Réseau Innovation 4.0” qui inclut 8 universités québécoises:
  - Grappe de Chaire 4.0 (FRQ)
  - Formation “Digitalisation de l’industrie manufacturière” (FONCER)
  - Infrastructures 4.0 (FCI)
  - “Forum International sur l’Innovation 4.0” (Novembre 6, 2019, Palais des congrès)

ÉTS Le génie pour l’industrie



Siemens Chair on Industry 4.0 Technology Integration

First Big Project in the Innovation 4.0 Hub ($5M/5 Years)

A Total Enterprise Industry 4.0 Integrated R&D Program*

3 Universities – 3 Projects – 20 Professors *(13 Profs. ÉTS in 3 Depts.)*

SIEMENS

Université Concordia University | ÉTS Le génie pour l'industrie | McGill

Engineering Design

Digital Multidisciplinary Analysis and Design Optimization "DMADO" Platform for Aero-derivative Gas Turbines (AGT) – *6 Profs (3 ÉTS)*

McGill Lead

Manufacturing

Development and Repair

Advanced Manufacturing Automation, Digitization and Optimization "AMADO" – *12 Profs (8 ÉTS)*

ETS lead

Supply Chain

A Digital Technology Platform for Supply Chain "DTPSC" – *7 Profs (4 ÉTS)*

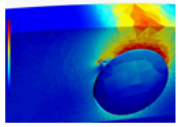
Concordia Lead

Total: $7M/5 years
(2018-2023)**

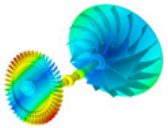
**A first in Canada*

***Including Siemens In-Kind*

Digital Multidisciplinary Analysis and Design Optimization "DMADO" Platform for Aero-derivative Gas Turbines (AGT)



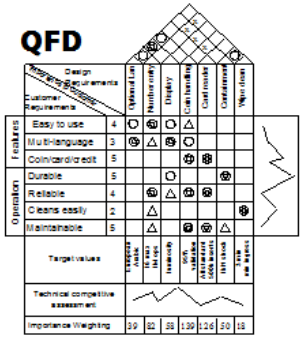
Combustion



Digital Platform

Design and Quality

Turbine



Requirements

Field and Test Data

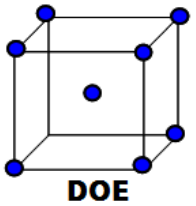
Project Management

Design Platform

Cost and Manufacturing

Design Tools

Product Definition

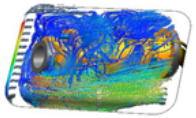


MDO

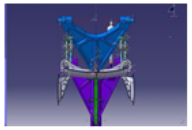
Parametric Design

Compressor

Controls



Performance



SIEMENS

Advanced Manufacturing Automation, Digitization and Optimization "AMADO"

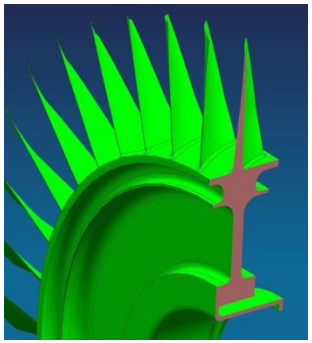
Advanced Condition Monitoring and Predictive Maintenance

Augmented Reality for Green Manufacturing Automation

Operational Logistics Digitization Technologies

Factory Data Analytics and Optimization

Advanced Manufacturing Automation, Digitization and Optimization



SIEMENS

A Digital Technology Platform for Supply Chain "DTPSC"

Scenario Planning and Forecasting

Transportation Management

Geometric and Data Mining for Extended Data Analytics

Multi-Tier Supplier Quality Management

Supplier Collaboration Platform

Cross-Disciplinary Workforce Development

SIEMENS

Réseau Innovation 4.0 Network

Created on Jan. 16, 2019

Domaines de recherche

1. Internet des objets (IoT) : *incluant l'infonuagique et la 5G*
2. Analytique des mégadonnées (*Big Data Analytics*) : *incluant l'intelligence artificielle (IA) et l'apprentissage machine (Machine Learning)*
3. Intégration des systèmes : *incluant la simulation, l'automatisation et l'optimisation de la conception, de la production et de la chaîne d'approvisionnement, et la gestion du cycle de vie du produit (PLM)*
4. Fabrication additive et intelligente
5. Réalité augmentée et virtuelle
6. Systèmes autonomes : *incluant les robots, les capteurs, etc.*
7. Sécurité informatique
8. Stratégies et approches pour virage numérique de la PME manufacturière : *incluant les diagnostics et les modèles d'affaires numériques, les démarches de transformation, les stratégies de fabrication et distribution, etc.*
9. L'humain au cœur de la transformation 4.0

Secteurs d'affaires

Manufacturier – Aérospatiale – Énergie – Santé et sécurité – Construction – Transport et logistiques – Minier – Pharmaceutique – Forestier – Télécommunication

Réseau Innovation 4.0 Network

Top Projects 2019

1. **Summer School 4.0** (End of August 2019)
2. **« Digitisation of the Manufacturing Industry » (**CREATE)
3. **Clusters of 8 Chairs 4.0** (FRQ)
4. **Joint FCI 4.0**
5. **First International Innovation 4.0 Forum** (6 november, 2019, PCM)

Leaders of Innovation 4.0 Network

Georges Abdul-Nour, Université du Québec à Trois-Rivières
Luis Antonio De Santa-Eulalia, Université Sherbrooke
Ygal Bendavid, Université du Québec à Montréal
Yaoyao Fiona Zhao, McGill University
Jean-Marc Frayret, Polytechnique Montréal
Jonathan Gaudreault, Université Laval
Hany Moustapha, École de technologie supérieure
Rolf Wuthritch, Concordia University

Réseau Innovation 4.0 Network

PREMIER FORUM INTERNATIONAL SUR L' INNOVATION 4.0

6 novembre 2019, Palais des congrès de Montréal

« Une perspective nationale et mondiale sur les technologies et les formations de l'Industrie 4.0 »

27 conférenciers: 14 de l'industrie, 8 des universités et 5 des associations et des grappes

Eric Schaeffer: auteur bien connu de deux livres sur « *Industry X.0 and Reinventing the Products* » et des hauts dirigeants des grandes organisations internationales:


E. Schaeffer


D. Di Perna


K. Stavrianos


K. Schmidt


T. Chevalier


K. Mahdi


L. Stojanovic


A. Ouellette

1000 participants et 7 sessions:

- *Perspective globale*
- *Fabrication intelligente*
- *Les usines du futur*
- *Les grappes/projets sur l'Industrie 4.0 des PMEs*
- *Internet des objets, Big Data et Intelligence Artificielle*
- *La main d'oeuvre et l'Industrie 4.0*
- *Innovation 4.0 dans divers secteurs industriels*

Pour le programme et les modalités d'inscriptions: reseauinnovation4network.com

En collaboration avec des conférenciers de: