

Automated Composite Manufacturing

Industry 4.0 School
University of British Columbia, The Okanagan Campus

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Canadian Manufacturing Overview

MANUFACTURING IN CANADA



CONTRIBUTES **\$173 BILLION TO GDP**, ALMOST
11 PERCENT OF THE CANADIAN ECONOMY

EMPLOYS **1.7 MILLION CANADIANS**

SPENT **\$6.8 BILLION ON
RESEARCH AND
DEVELOPMENT** IN 2014

TOP THREE MANUFACTURING SECTORS BY SALES IN 2014:

• TRANSPORTATION
EQUIPMENT
\$112.6 BILLION



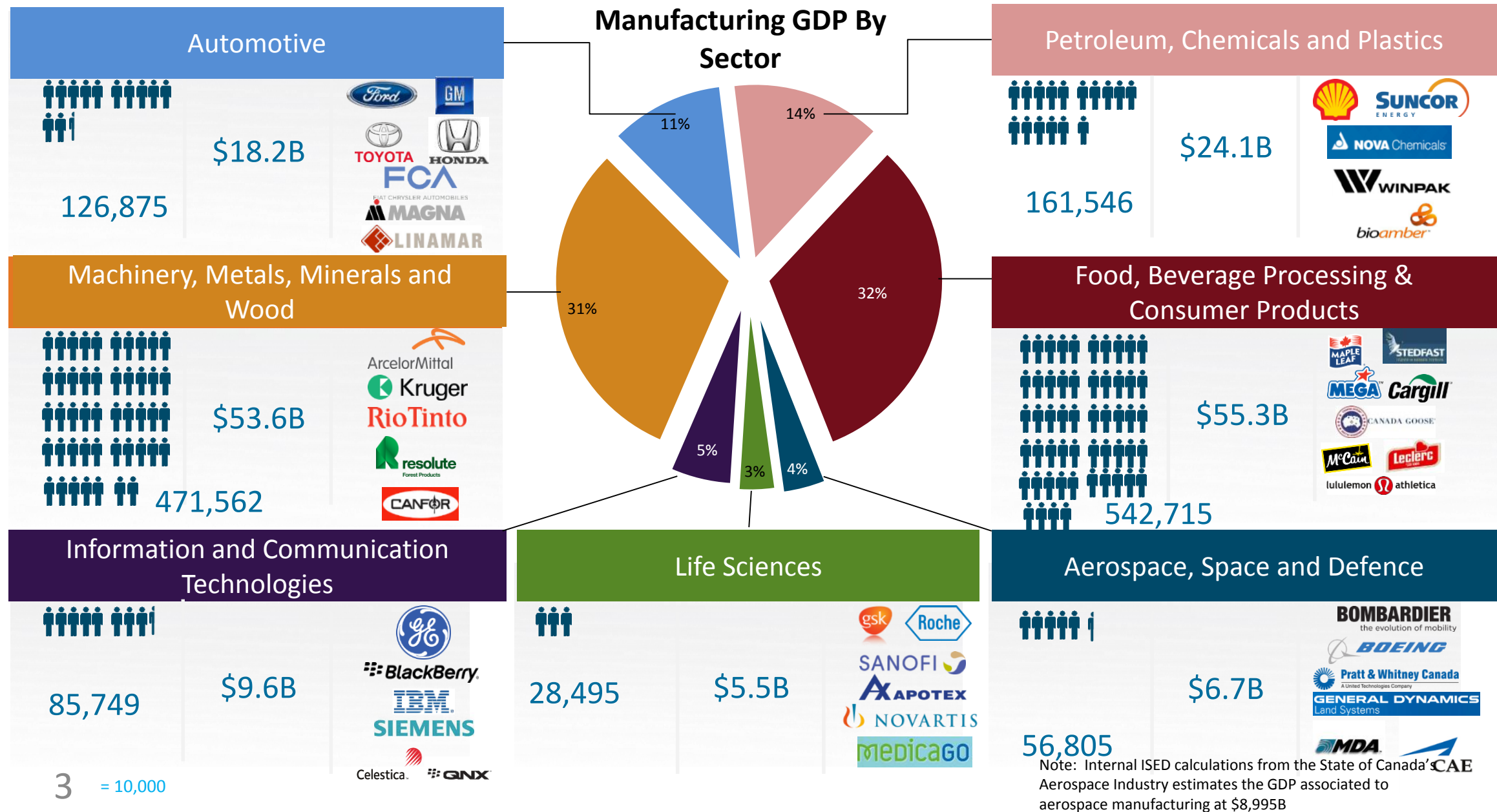
• FOOD PROCESSING
\$107.1 BILLION



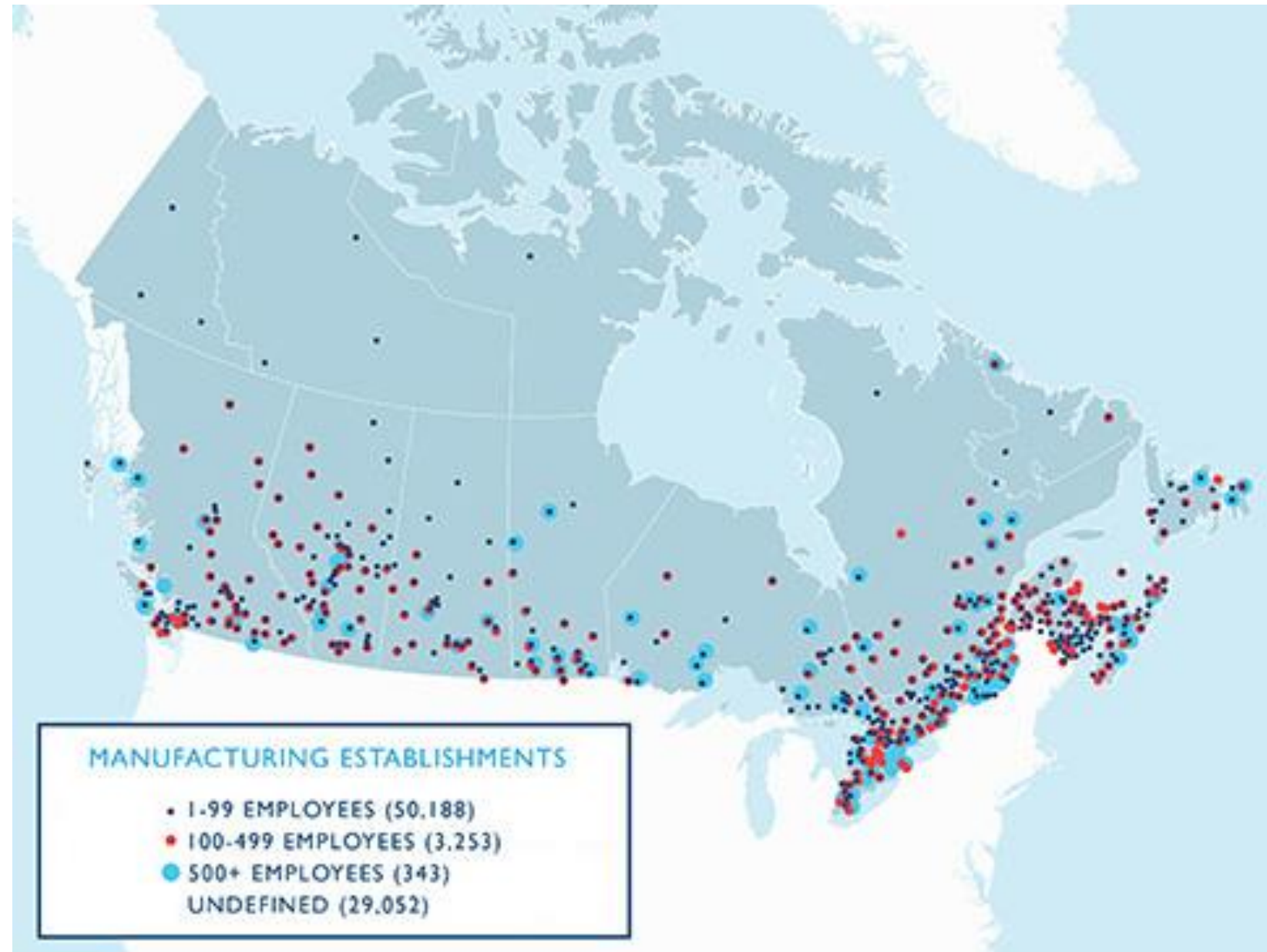
• PETROLEUM AND
COAL PRODUCTS
\$83.1 BILLION



Canada's Manufacturing Sector - Strong and Diversified



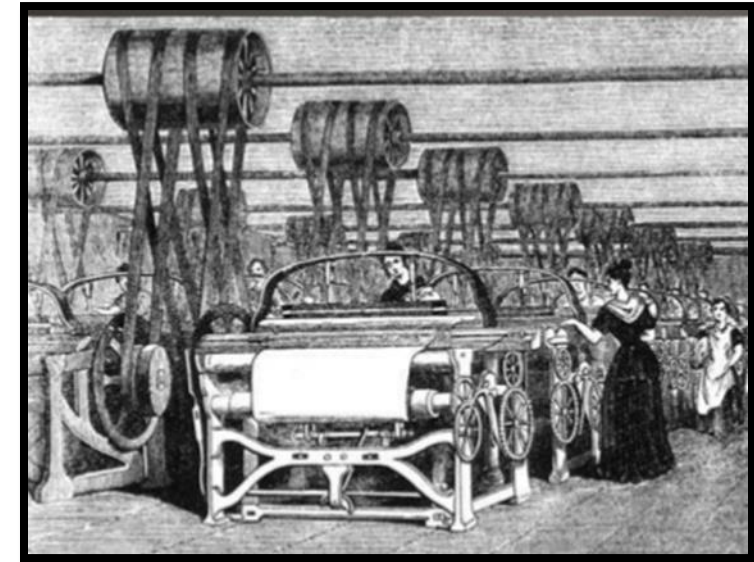
Manufacturing Establishments



Industrial Revolutions

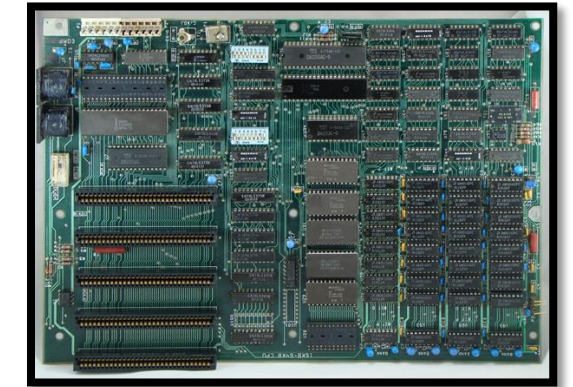
- 1st Industrial Revolution (1760-1900)
 - Use of hydro power and steam power in manufacturing plants (Steam Engine)

- 2nd Industrial Revolution (1900-1970)
 - Use of electric power in manufacturing plants (Mass Production)



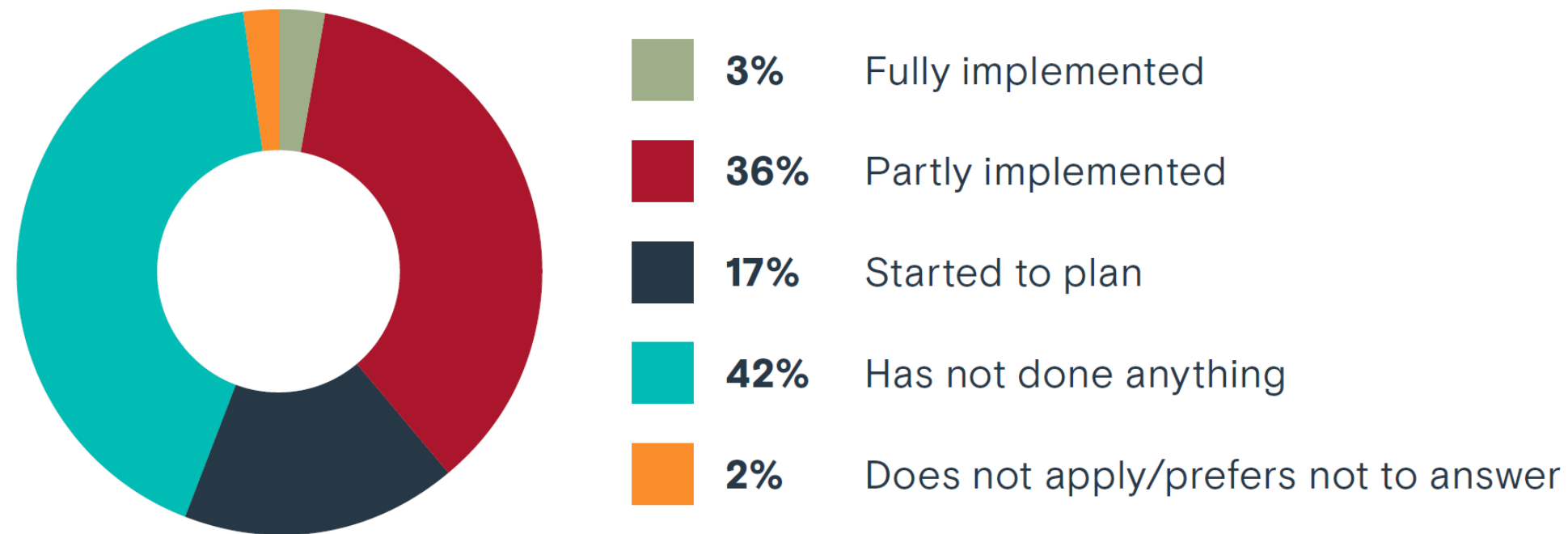
Industrial Revolutions

- 3rd Industrial Revolution (1970 to date)
 - Use of electronics, IT, controls, and computers in manufacturing plants (Automated production)
- 4th Industrial Revolution (Today → Future)
 - Use of digitalization at process and system levels, Internet of Things, artificial intelligence, cyber physical systems



Industry 4.0 in Canada

To what extent have you implemented digital technologies (Industry 4.0 projects) in your company?

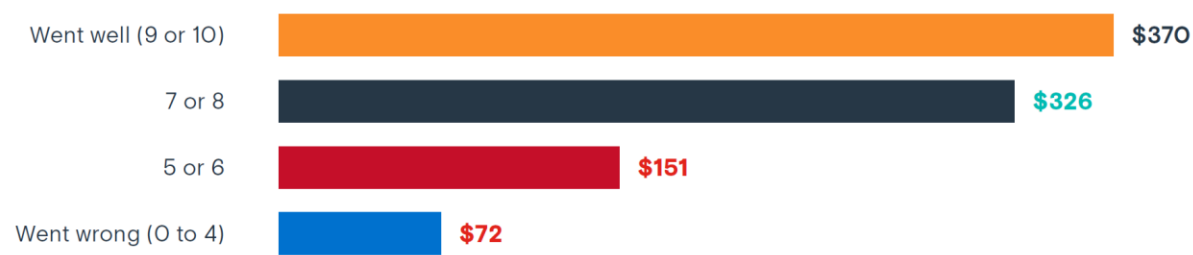


Source: Ad Hoc Research, Survey on Industry 4.0 in the Canadian manufacturing sector, 2017.
Base: All respondents (n=960).

Industry 4.0 in Canada

Average investment in Industry 4.0 projects in the past two years
(in thousands of dollars)

How well did implementing Industry 4.0 projects go in your case?



How ready are you to adopt new Industry 4.0 technologies?



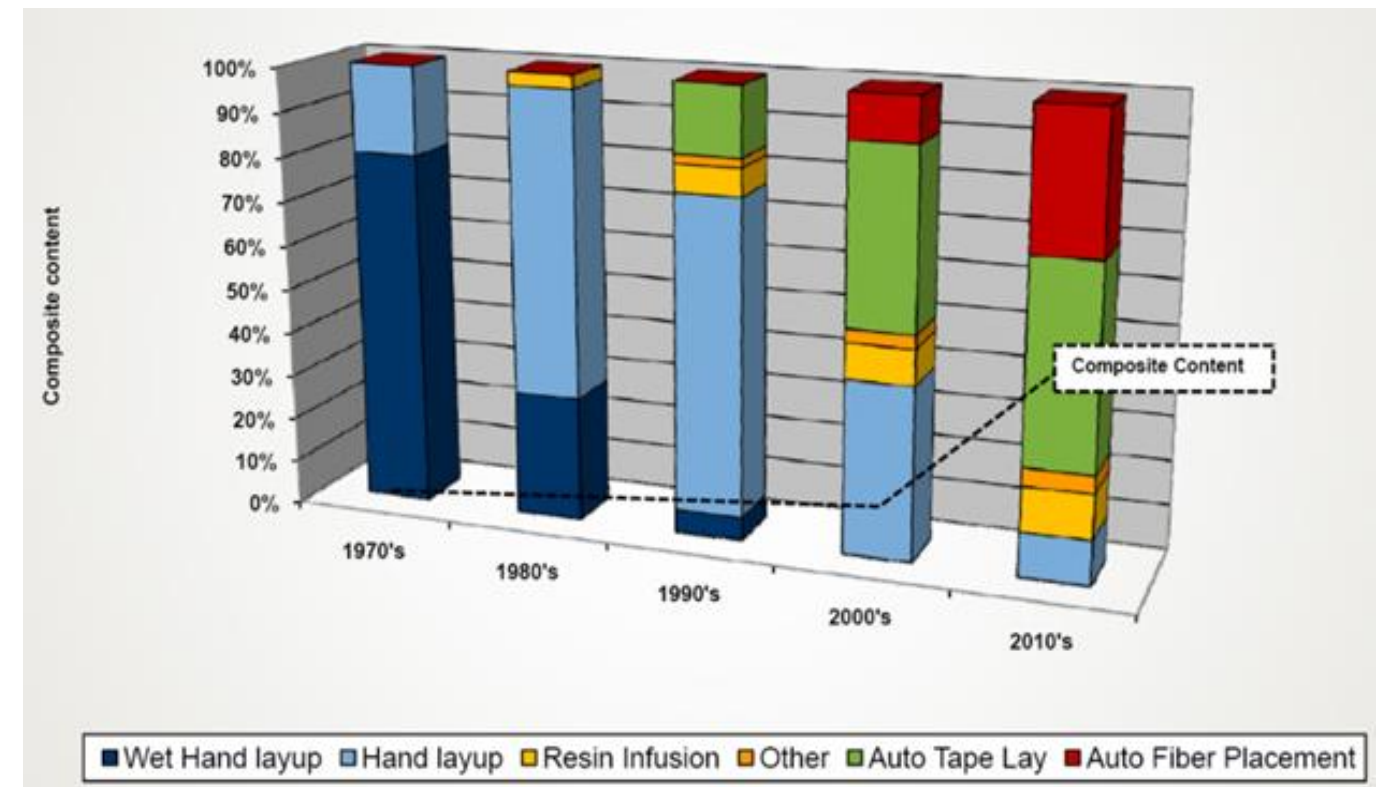
However, overall investment in these technologies remains low, a sign that **Canadian manufacturers still have a long way to go to catch up with their international competitors.**

Figure 6 – The majority of manufacturers invested less than \$100,000

Composite Manufacturing and Industry 4.0

Evolution of Composite Manufacturing

- Evolution of processes and materials
 - 1970's: Wet hand lay
 - 1980's: Prepreg hand lay up
 - 1990's: Prepreg hand lay up/Start of automated tape placement
 - 2000's: Automated tape placement /Start of Automated fiber placement
 - 2010's: More domination of automation



Shumate, 2011

Automation in Composite Manufacturing

- Improved design flexibility and part reproducibility
- Minimized manufacturing cycle time
- Reduced labor intensity and cost
- Reduced material scrap
- Reduced process variability due to human errors and instability
- Improved quality and productivity
- Increased assembly and maintenance efficiency

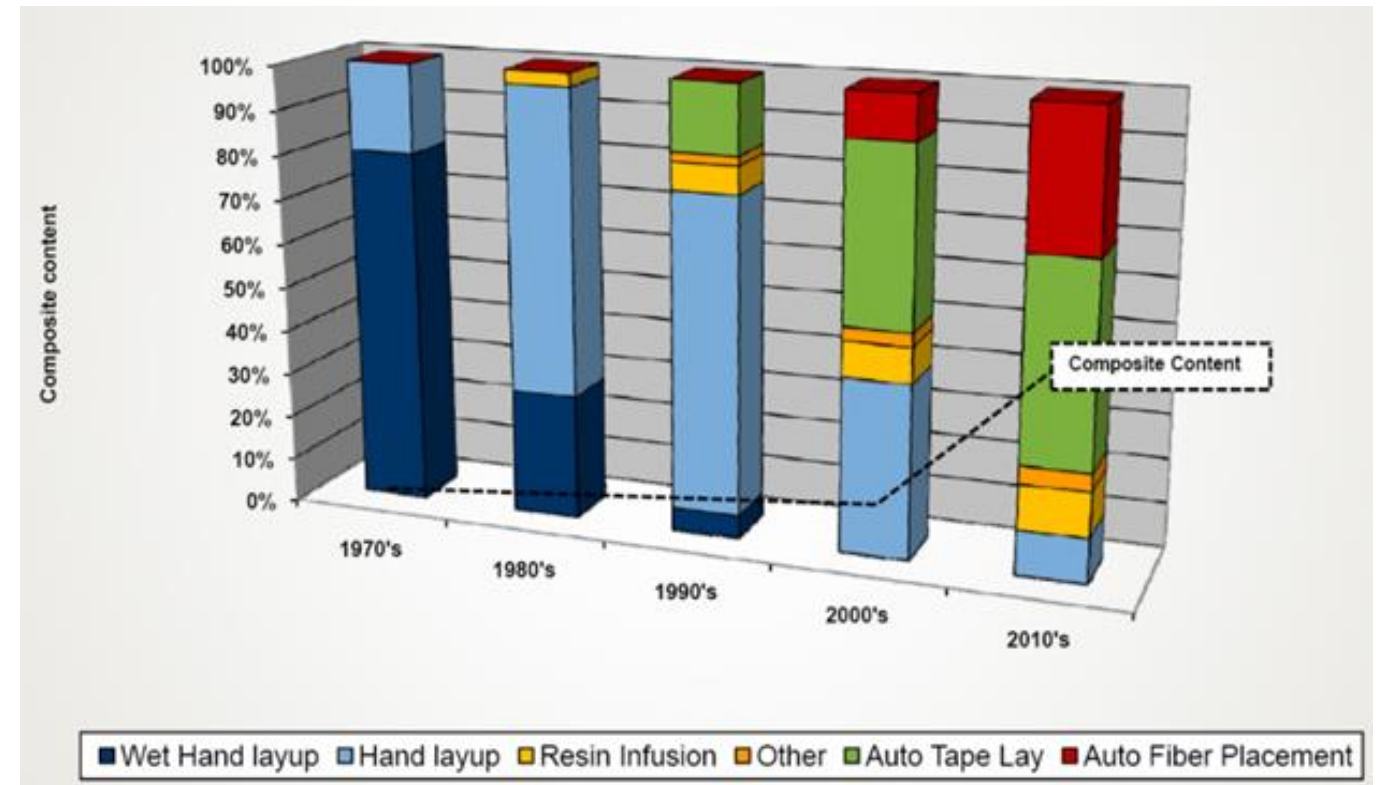
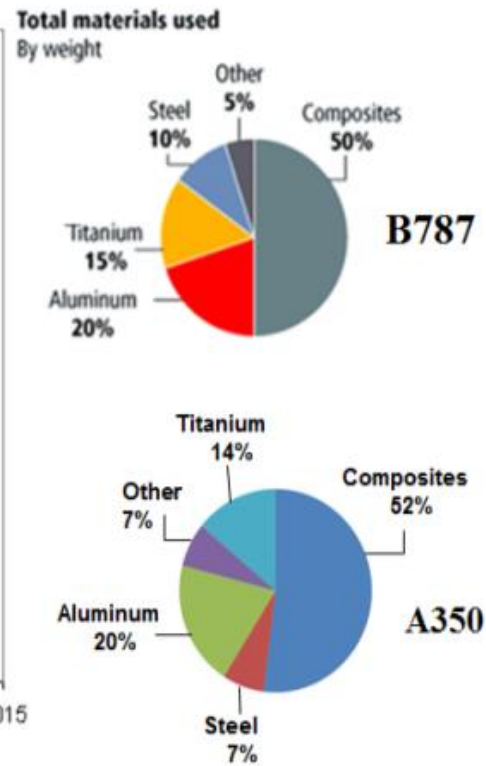
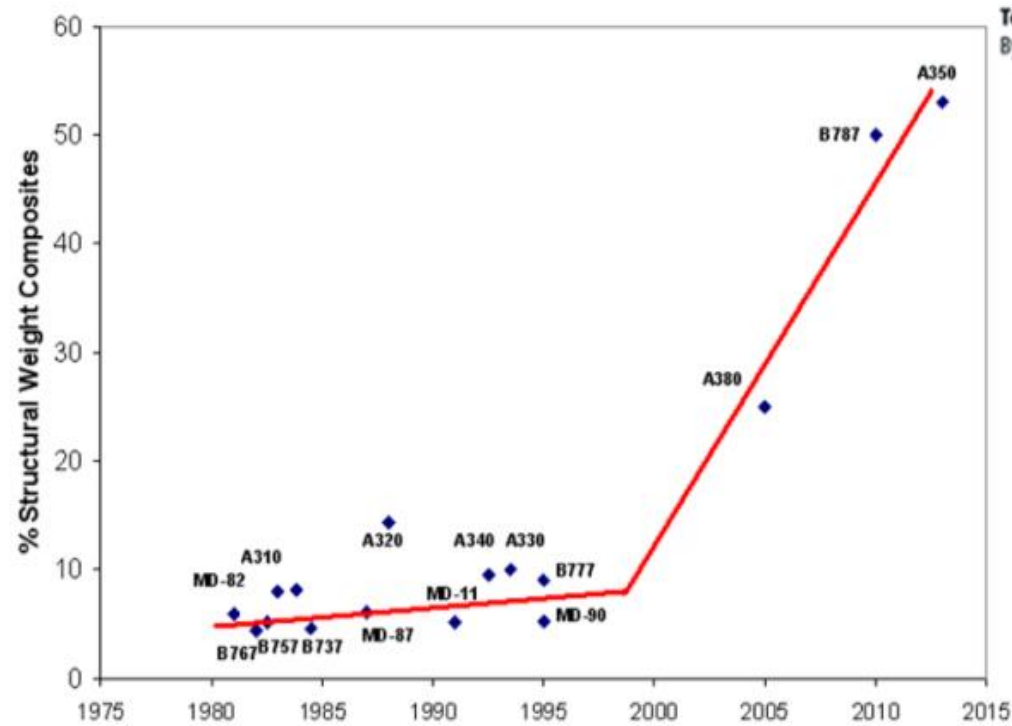


ATL process



Automated fiber placement

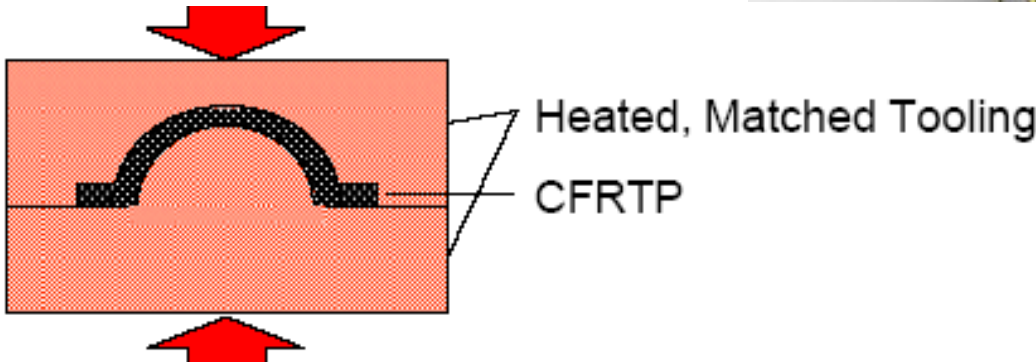
Effect of Composite Automation in Aerospace



Transformation in Composite Forming Technology

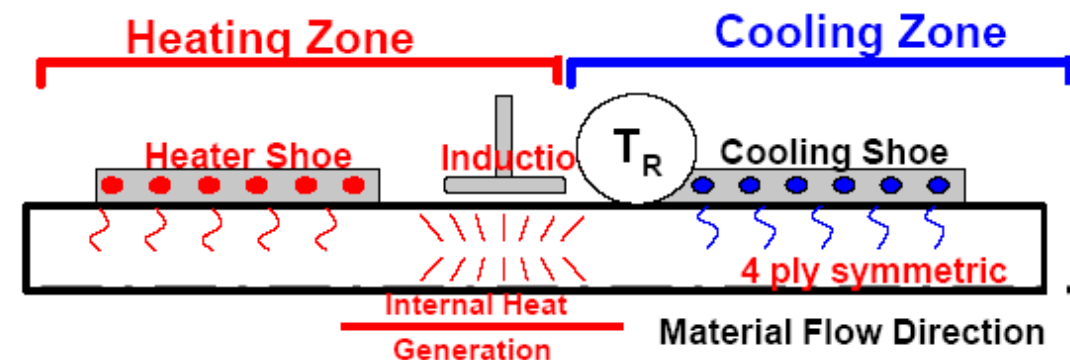
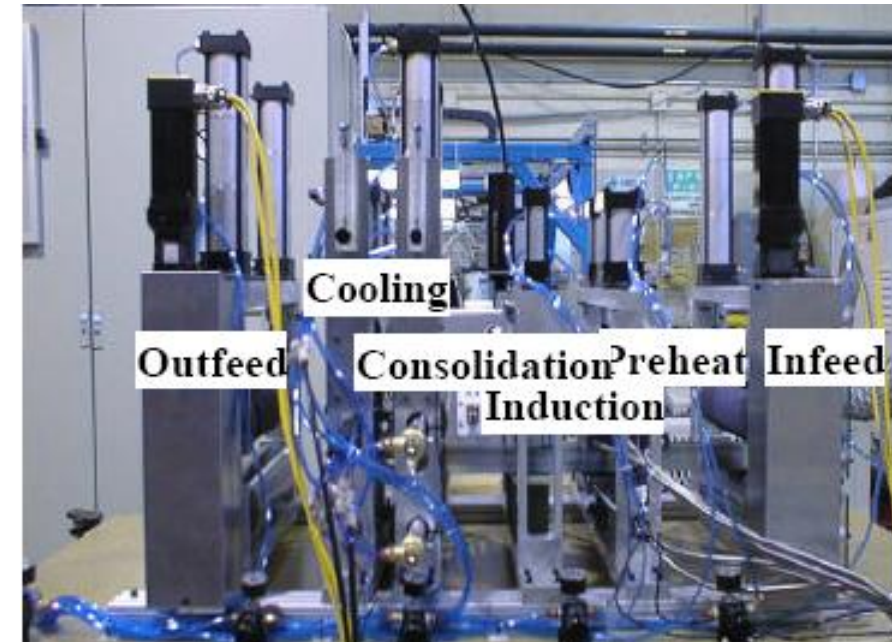


Substantially enhanced by
Automation and digital
capabilities



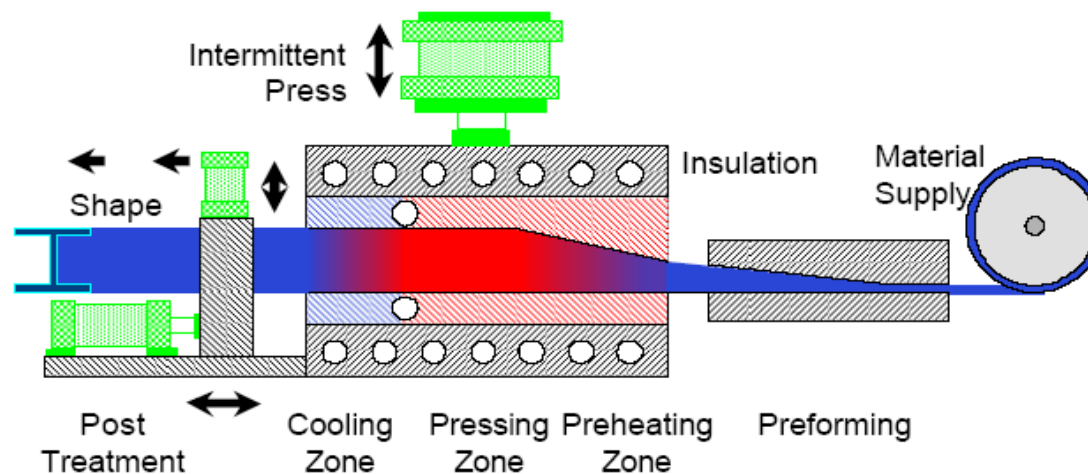
Rapid Automated Induction Lamination

- **Part Configuration:**
 - Sheet, simple shapes
- **Fabrication Technique:**
 - Automated continuous lamination using induction heating source
- **Raw Material Form:**
 - Fully impregnated prepreg
- **Process Variants:**
 - Heating technique
 - Stamping die
- **Advantages/Disadvantages**
 - Inexpensive route for sheet and simple shapes
 - Must be conductive fiber and multiple orientations to create inductive heating



Continuous Compression molding

- **Technique:**
 - Incremental Compression Molding Process
- **Part Configuration:**
 - Sheet, constant section profiles
- **Raw Material Form:**
 - Fully impregnated prepreg
- **Process Variants:**
 - Flat sheet and stamping die
- **Advantages/Disadvantages**
 - Inexpensive route for sheet and simple shapes
 - Specialized equipment

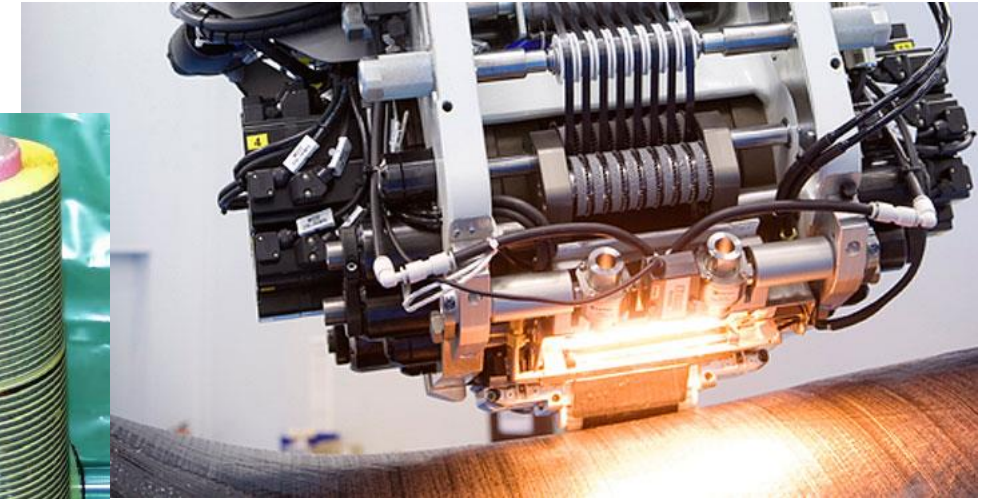


Composites Manufacturing and Industry 4.0



Automated Fiber Placement:

- Individual tow is coming from several spools fed into a fiber placement head.
- They are collimated into one fiber band (Course)
- The course is laid down and compacted onto a tool by the application of heat and pressure.
- At the end of the course, the tows are cut
- The head is positioned to the beginning of the next courses.
- The multi-axis control of the placement head enables large scaled composite parts with complex contoured surfaces.



Automated Composite Manufacturing: example

- Current Process flow for AFP:
 - Automation brings efficiency in composite manufacturing



Automated Layup



Ply-by-Ply Inspection

Bagging

Cure

Non-Destructive Inspection/Machining

Can we do better? How and Where?

Automated Composite Manufacturing: example

Typical process Distribution:*

- Machine layup time 27%
- Inspection and Repair 32%
- Process errors 14%
- Everything else that happens 27%

*Source: GKN Aerospace (A350 XWB rear wing spar)

Online Process **Inspection and sensing** as **Enabling Technologies** to enhanced Manufacturing Efficiency and Process Digitalization



Automated Layup with in-situ Inspection

Bagging

Cure

Non-Destructive Inspection/Machining

Automated Composite Manufacturing: example

Development and implementation of innovative manufacturing technologies integrated with **Sensor technology**



Automated Layup with in-situ Inspection

Bagging

Cure

Non-Destructive Inspection/Machining

Smart/Flexible end-effector

Automated bagging process with integrated sensors
"Bag-free cure"

Smart Curing

Fully Robotic Inspection and machining

Automated Composite Manufacturing: example

Digital Twin, Process Simulations and Big Data management/analysis of each process

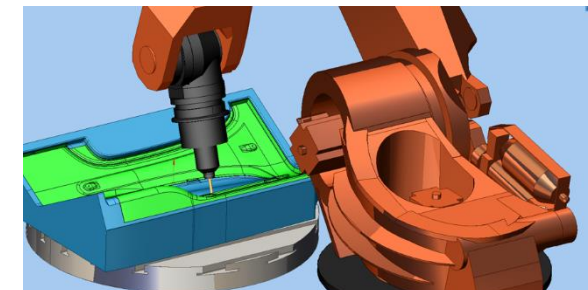
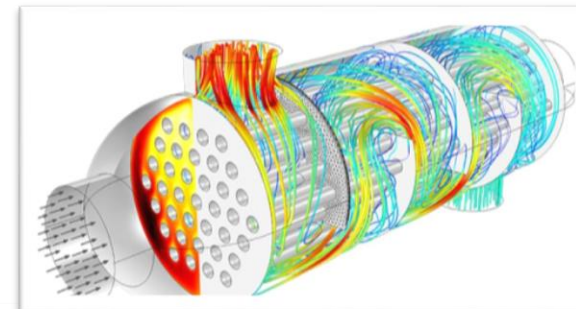
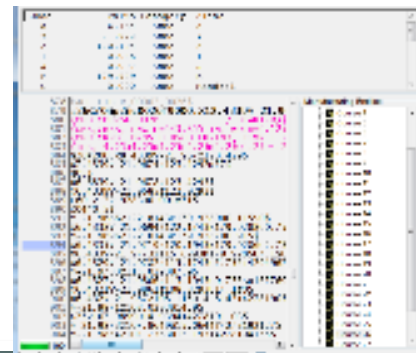
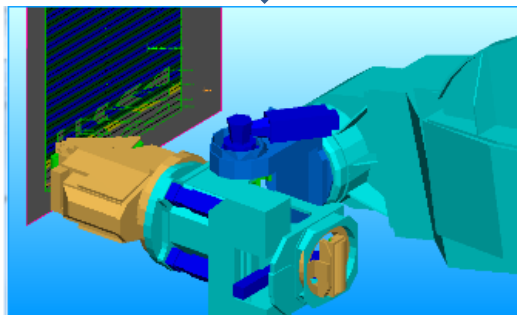


Automated Layup

Bagging

Cure

Non-Destructive Inspection/Machining



Automated Composite Manufacturing: example

Connectives, IoT, Decision Making, and AI

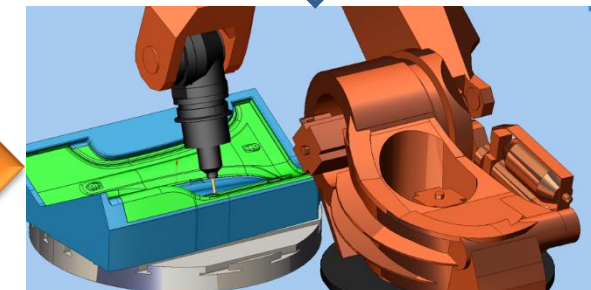
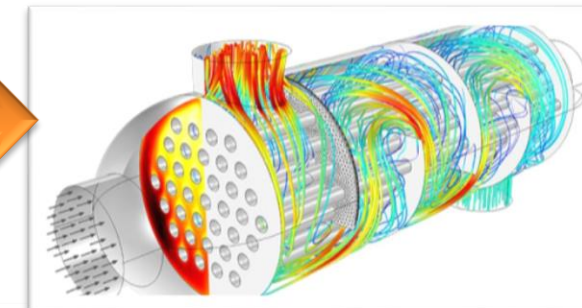
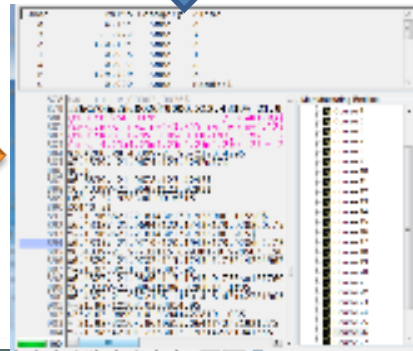
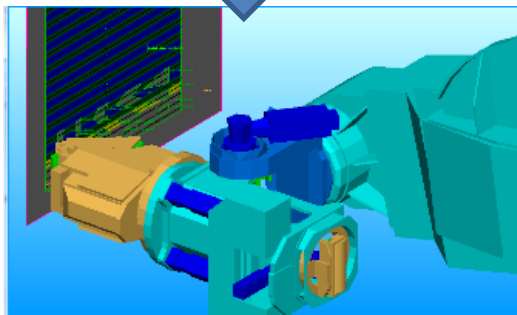


Automated Layup

Bagging

Cure

Non-Destructive Inspection/Machining



Automated Composite Manufacturing

Development and implementation of innovative enabling technologies to enhance **manufacturing efficiency** of composite products with **digital transformation** of processes/manufacturing cells in order to move towards Industry 4.0 concepts.





Thank you!