



# Aerospace research at ÉTS

## Materials and manufacturing activities

Canadian Aerospace R&D Mission to Poland

March 2009

# ETS Performance in Canada

- The student body of ETS stands today at **5000**, and every year **1500** new students are admitted. ÉTS currently graduates 1 in 4 new engineers in Quebec.
- Among the three largest Professional Engineering Schools in Canada, largest in Quebec (2006 undergraduate student population)
- 1<sup>st</sup> Engineering School in Canada for its social and environmental academic content (Corporate Knights 2006)
- Largest engineering Coop program in Canada with more than 2,200 job placements/year in more than 900 companies

*NOTE : there are 36 Professional Engineering Faculties/Schools in Canadian Universities*



# ETS Performance in Canada

- 700 students enrolled in 2<sup>nd</sup> and 3<sup>rd</sup> cycle programs
- 125 researchers in 30 research groups, 600 publications per year
- 4 Canada Research Chairs & 3 industrial chairs
- Source of external R&D funds: 49% from industry (over 100 companies)
- 2<sup>nd</sup> among Canadian Universities for the annual growth in external research funding (Research InfoSource 2007)

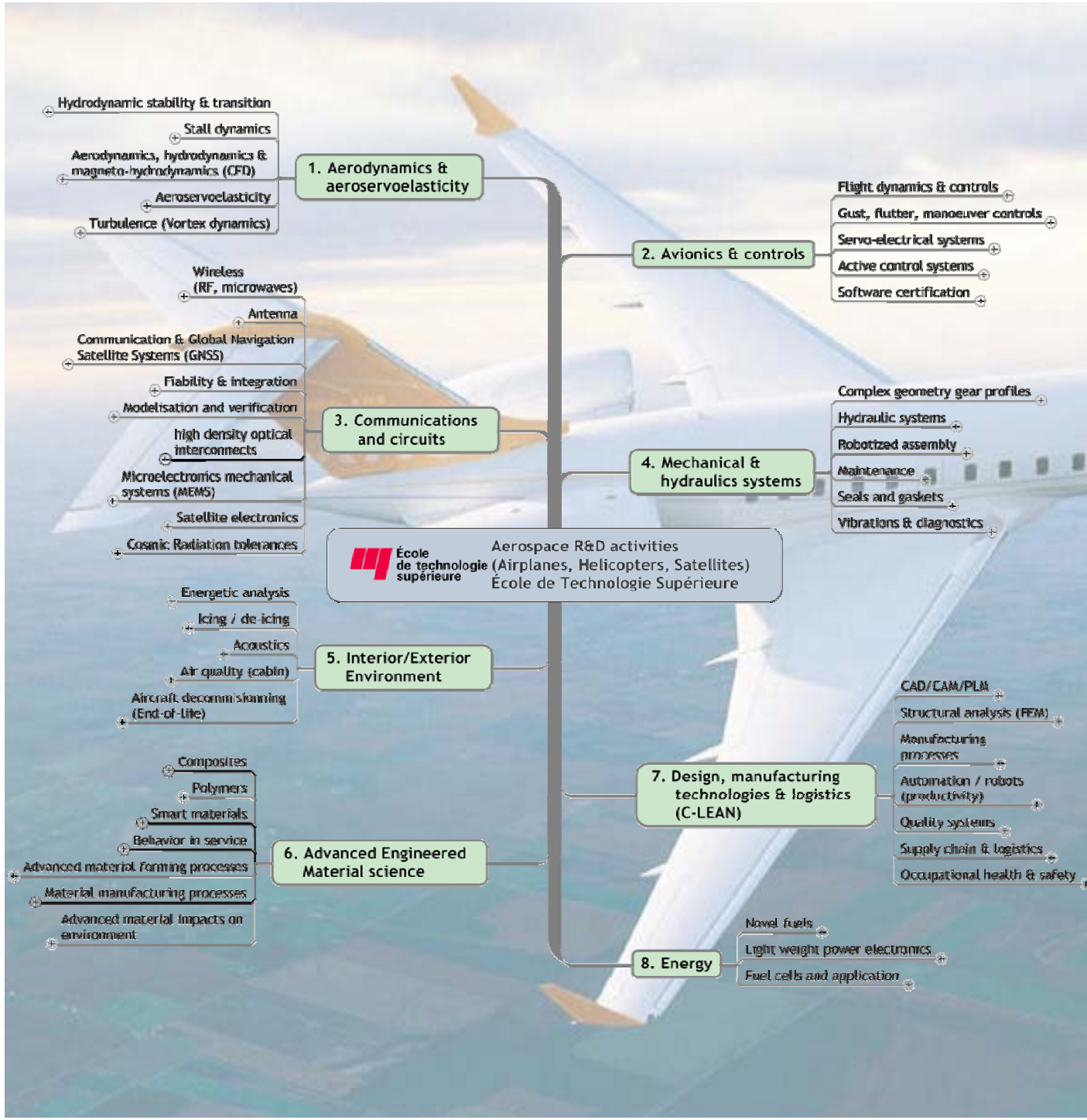


# International Relations Office

- Increase the mobility of the students of the ÉTS
- Welcome foreign students to the ÉTS within the framework of exchange programs
- Reinforce and develop new international scientific collaboration relations
- Collaborate in international development projects
- Contribute to the strategic influence of the ÉTS

<http://www.etsmtl.ca/english/international.html>





Aerospace research programs	(2006-07)
Aerospace researchers (main expertise in Aerospace)	13
Aerospace researchers (expertise also applies to aerospace)	25
Aerospace graduate students	70
Aerospace undergraduate students	105
Aerospace Publications (peer review)	75
Aerospace research projects (Nb/Value)	25 / 17,5 M\$

Milling, drilling trimming and routing optimization of multilayer material Al-Li/Ti/composite

Automated deburring and polishing processes optimization

Optimization of the brazing process of alloys used for joining different aerospace alloys used in gas turbine engines

Effect of bulk residual stresses on the final geometry of machined parts

Tolerance control for non rigid parts

Application of the spinning process combined with heating strategy for manufacturing axisymmetric parts made of aerospace alloys

Develop and optimize brazing welding to create structural joint in superalloys and Ti alloys

Search and Compare 3D geometry 3D Geometry Analysis

Residual stress prediction after welding + hammer peening processes

Development of brazing process applied to martensitic and austenetic stainless steels and nickel superalloys

High performance machining of light alloys, thin-wall parts for aeronautic industry

Burr prediction, avoidance & robotic deburring

Friction stir welding Al alloys

Integrated Product-Process change management

Induction hardening of bevel gears for aerospace applications

Drawingless Product development process



Ti machining optimization through software prototypes development

Process and materials for repairable anti-corrosion coatings

High performance milling of monolithic Aerospace Structures

Demonstrate the reliability and repeatability of an automated non-destructive testing (NDT) system combining different probes

Robust machining processes

Direct laser deposition

Optimization of high performance machining of light alloy aerospace components

Product design optimization with integration of computational tools



Process modeling tools development for the virtual manufacturing of aerospace components by tube hydroforming



Manufacturing Related Research Programs



Understanding the water erosion of compressor blades in the turbine engines and developing cost effective water erosion resistant coating

Closed door machining in-process measurements

Cell automation

Off-line robot programming



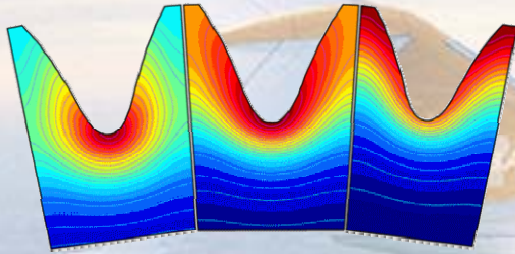
Development, processing and testing of new environmental barrier coatings for ceramic matrix composites

# Contour hardening by dual frequency induction hardening

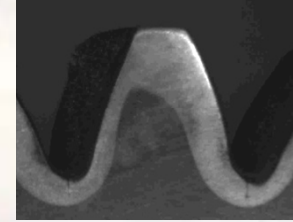
*Prof. Philippe Bocher*



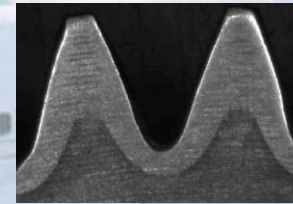
Modeling the induction process



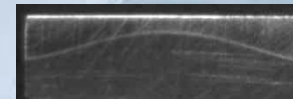
Application to helicoidal gears



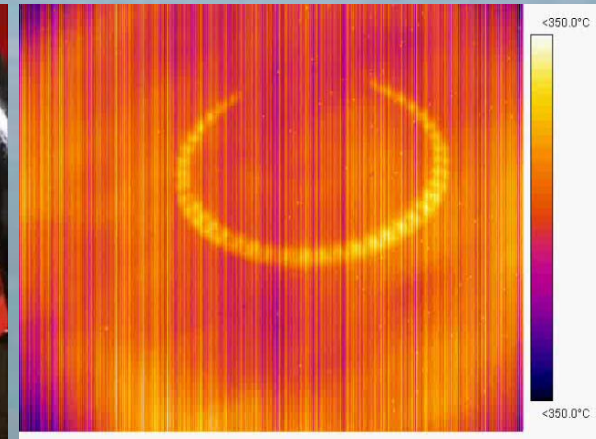
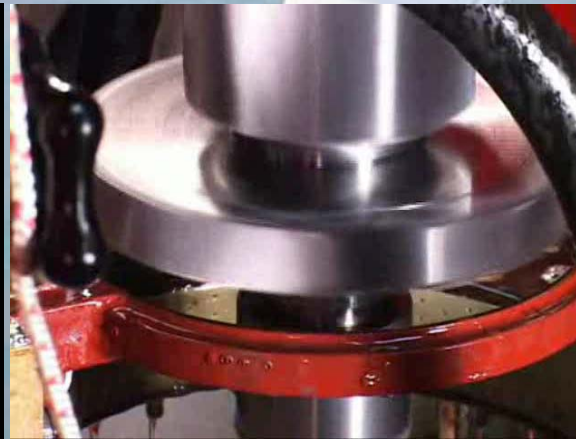
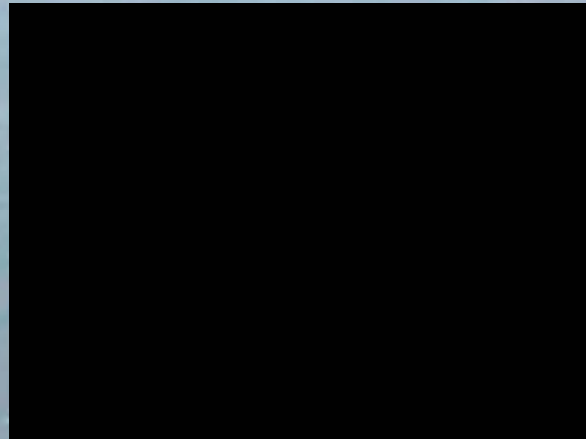
Controlling edge profile



Controlling edge effects

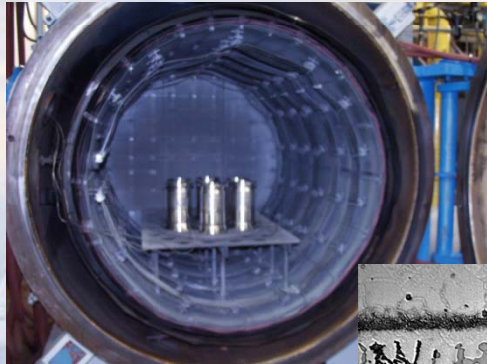


Fatigue and pitting performance

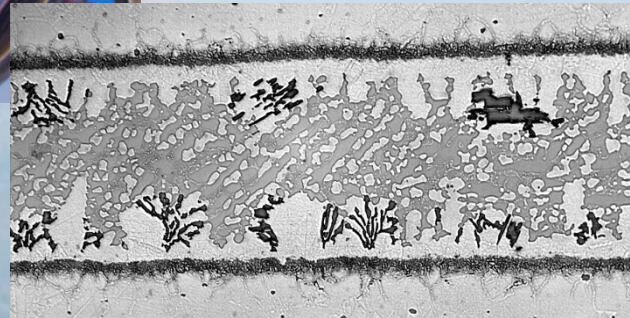


# Brazing of superalloys

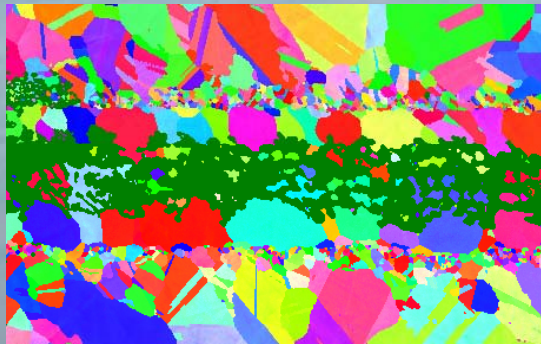
Prof. Philippe Bocher



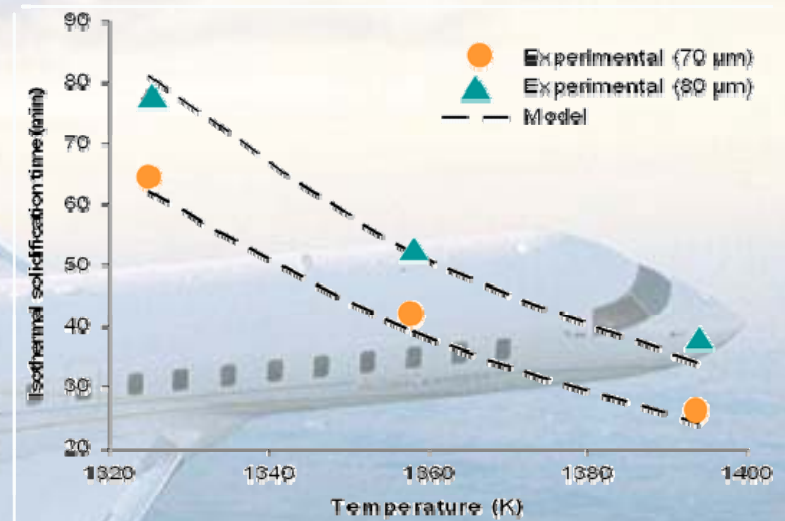
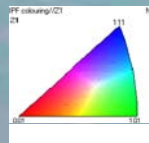
Process control and optimisation



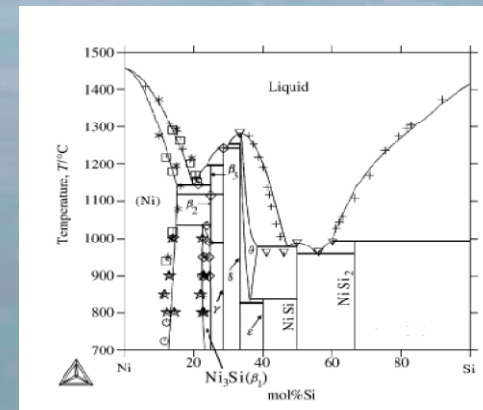
Crystallographic analyses (EBSD)



Identification of the brazing mechanisms



Kinetic and thermodynamic modelling



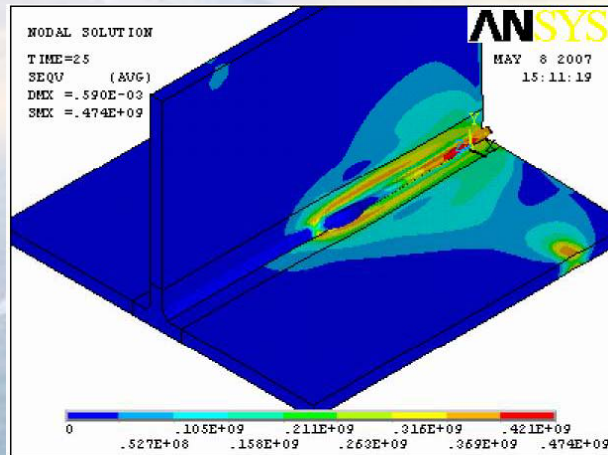


# Residual stress prediction after welding + hammer peening processes

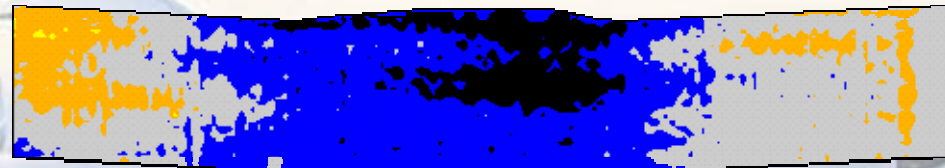


Profs. Philippe Bocher, Henri Champlaud, Van Ngan Le

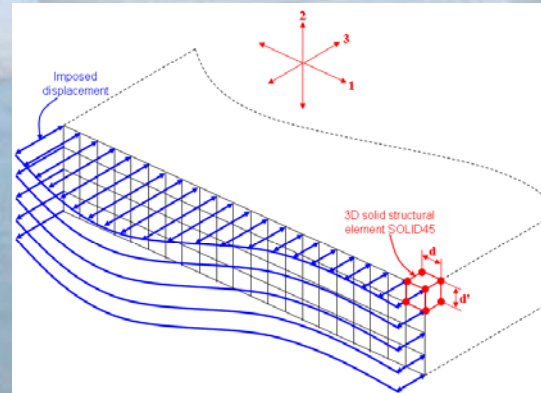
## Residual stress modeling



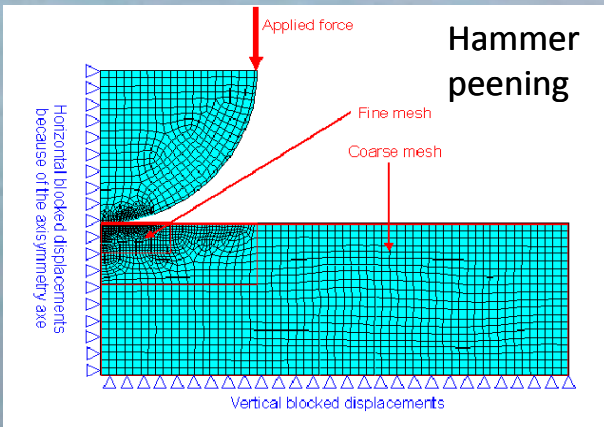
## Residual stress measurement



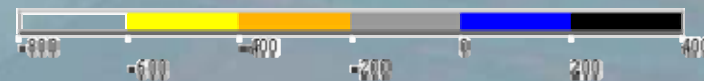
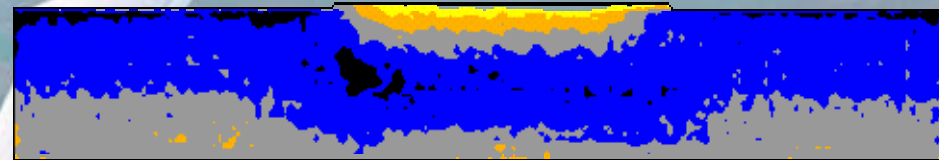
## Welded structure



## Welded structure



## Welded + Hammer peening



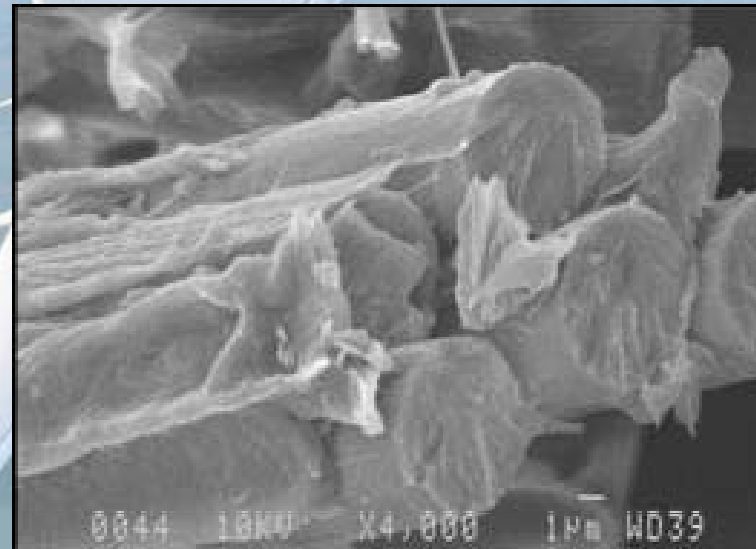
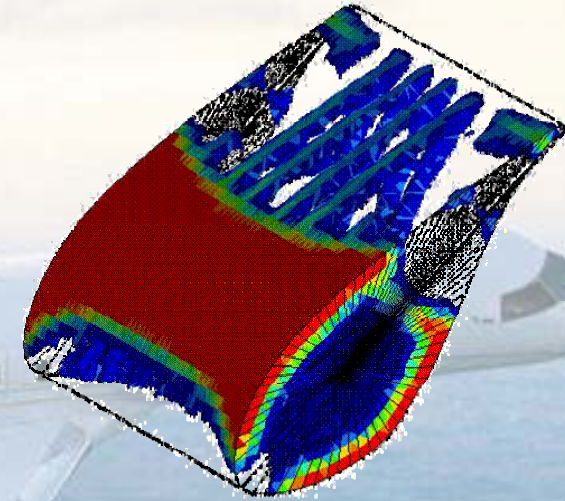
# Fibre-reinforced Composite Materials

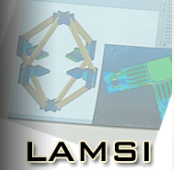
*Profs. Simon Joncas, Anh Dung Ngô*



## Research activities

- Re-use and recycling of composites
- Freeze-thaw cycles effects on composites
- Mechanical testing
- Experimental testing and validation (MTS, DSC, DTMA, etc.)
- Structural design of wind turbine blades
- Natural fibre composites
- Finite Element Analysis – Fracture Mechanics – Fatigue
- Environmental Effects on Mechanical Behaviour





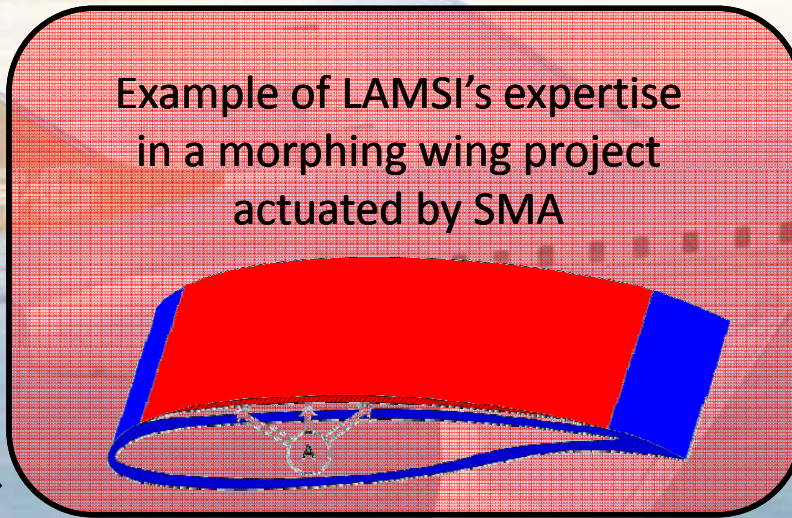
# Shape Memory Alloys Intelligent Systems

*Profs. Vladimir Brailovski, Patrick Terriault*



## Design of new SMA applications

- Flexible structures
- Actuators
- Dampers

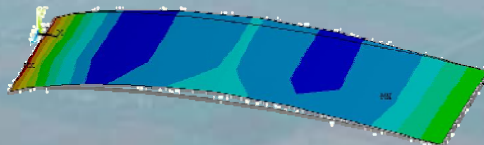


## Material Characterization

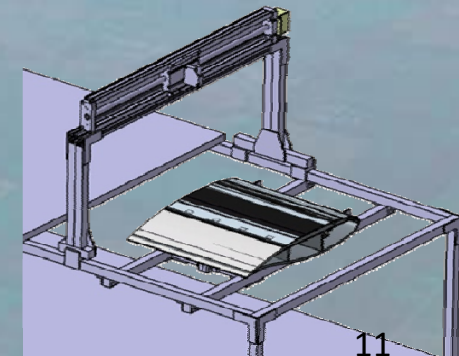


## Finite Element Simulations

- Composites
- SMA



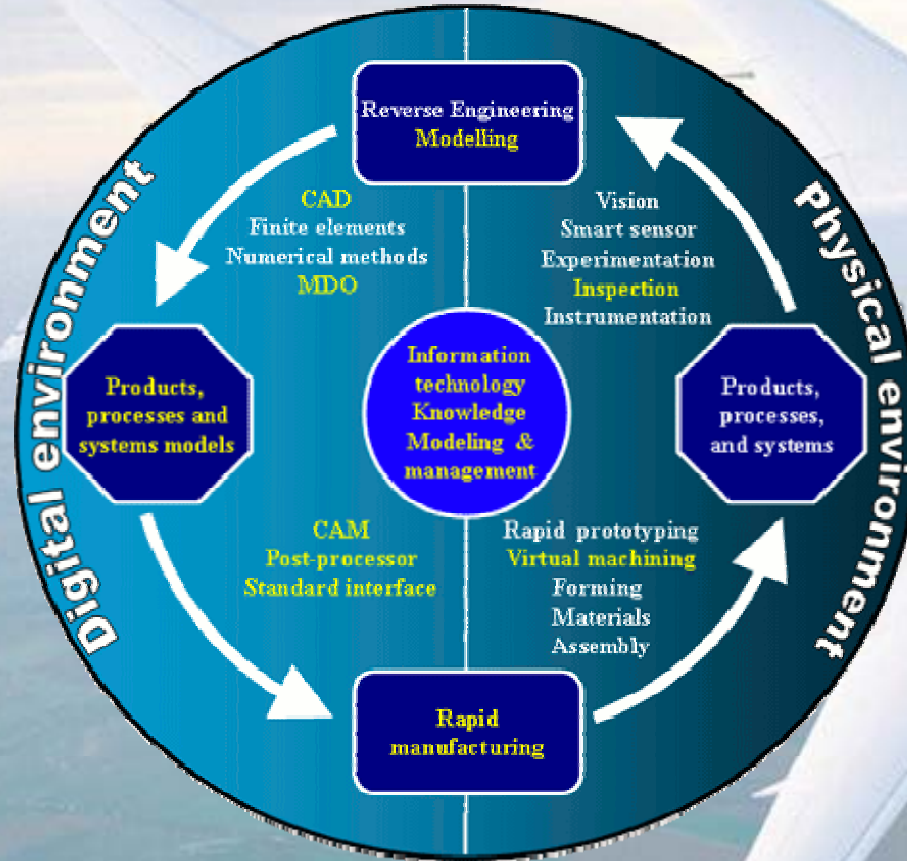
## Mechanical Design



## Manufacturing and thermomechanical treatment of SMA

# Manufacturing = P2SEL

## Products, Processes, and Systems Engineering Laboratory



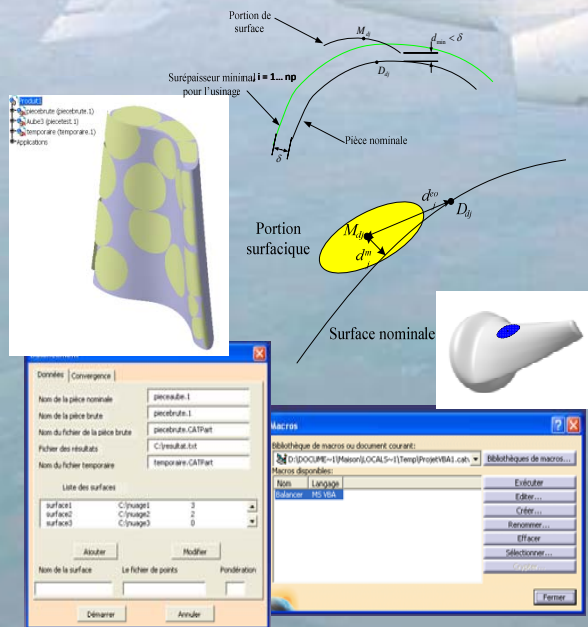
The mission of the Products, Processes, and Systems Engineering Laboratory (P2SEL) is to train researchers and highly qualified personnel, and to conceive scientific developments and applied research resulting in the production, validation, and optimization of products, processes, and systems by applying a multidisciplinary and global approach.





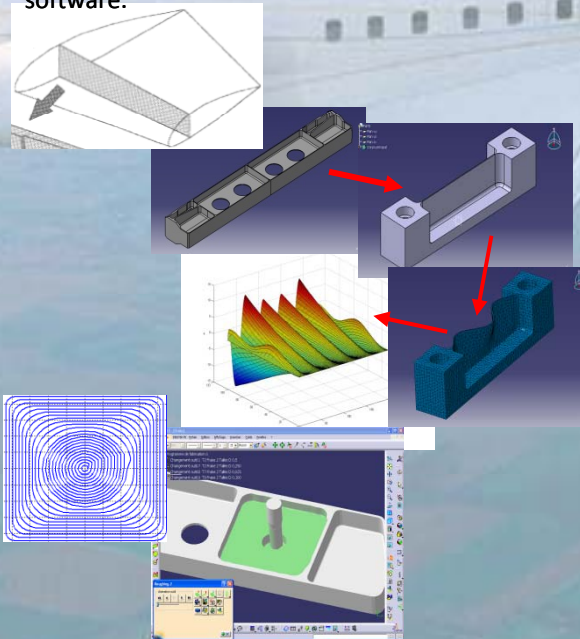
## 3D localization algorithms for complex part machining and tolerance verification

Development of new approaches and algorithms for the verification/correction of in-process machining of work pieces through localization of dense data files with respect to a CAD nominal model. Geometric and dimensional tolerance verification integrated within the CAD/CAM development process for a part. Development within the CATIAv5 application software.



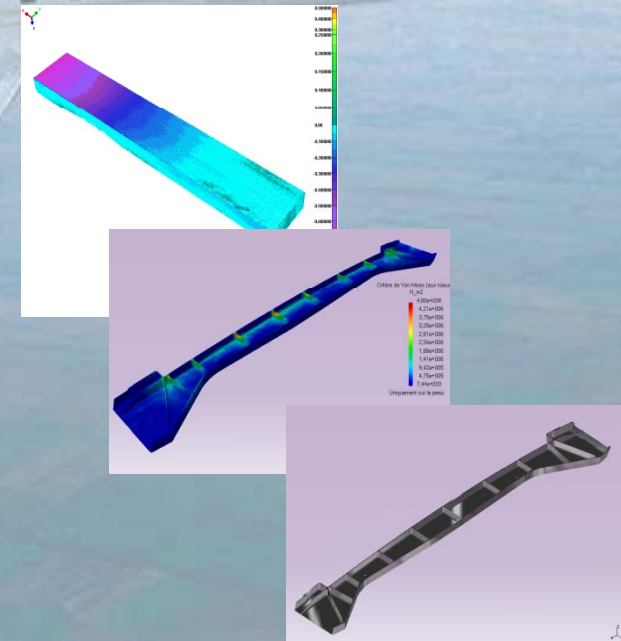
## High performance machining : optimization of thin walls and webs machining for aerospace parts

Development of models for proactive control of surface finish (profile) resulting from thin walls machining. Numerical simulation considering tool and wall deflection during the finishing step of machining operations. Development of new approaches and toolpaths for high speed roughing of parts with pockets. Algorithms integrated within the CATIAv5 application software.



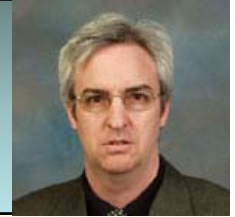
## Prediction of part deformation in high speed machining of aerospace structural parts

Residual stresses are of severe concern during the machining process of a part. It directly influences the process planning for parts with tight tolerances. This research aims to analyze and comprehend the deformation phenomenon of parts in order to rationalize their manufacturing process through prediction models.



# Machining of composites and multi-layer materials

*Prof. Jean-François Chatelain*

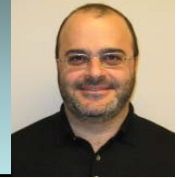


- Find optimal cutting conditions for the machining of aerospace laminated parts with quality assessment in terms of dimensional, form, roughness, and structural integrity of the laminates
  - Drilling of a multi-layer material; carbon-epoxy / Al / Ti
  - Trimming of a multi-layer material; carbon-epoxy / Al / Ti
  - Trimming of a carbon-epoxy composite material
  - Multi-axis milling of a carbon-epoxy composite material
- Develop a prediction model to prevent delamination based on cutting forces and torque (machining conditions) for the drilling and the trimming operations
- Propose new cutting tool geometry and material for cost effective operations
- Develop a prediction model for costs of operation based on the type of cutter and its optimal machining conditions



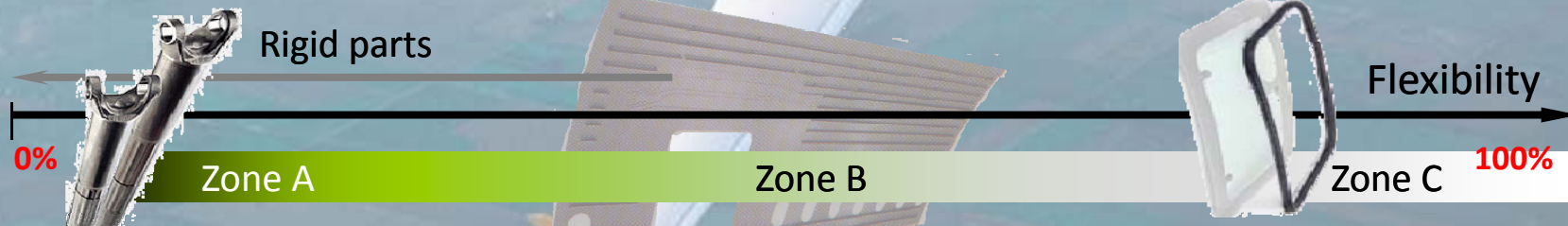
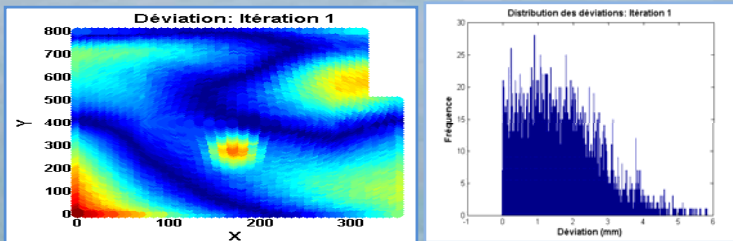
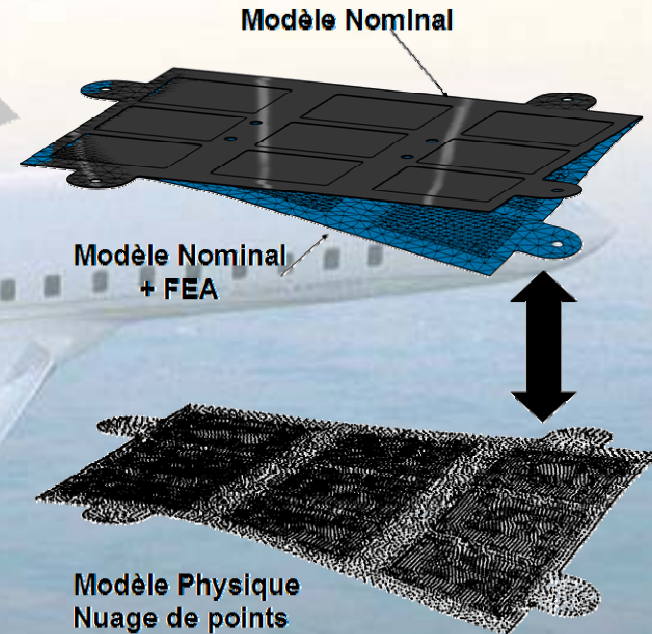
# Analyzing tolerance of non rigid parts

Prof. Antoine Tahan



## Elimination templates conformation (Virtual Fixture)

- Simulation forces during assembly
- Identification of real geometry
- Analyzing profile tolerances



# Non-destructive testing / Process instrumentation

Prof. Martin Viens

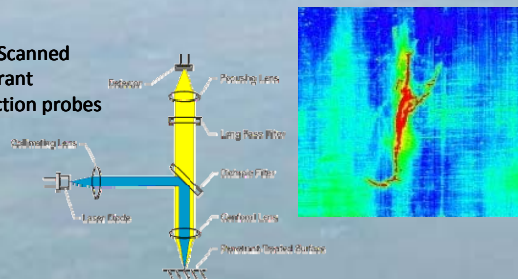


## Automation of non-destructive testing processes

### Objectives

- Development of a digital image acquisition system for fluorescent penetrant indications
- Development of an eddy current model to estimate depth and shape of cracks based on multiple-frequencies measurements
- Integration of FPI and eddy current techniques in a fully automated inspection system
  - Conception of specialised end-effectors to fit industrial robots
  - 3D profile evaluation of a part and automatic generation of tools scanning paths
  - Development of data processing algorithms to recognize and classify defects

### Laser Scanned Penetrant Inspection probes



### Cracks evaluation with eddy current measurements



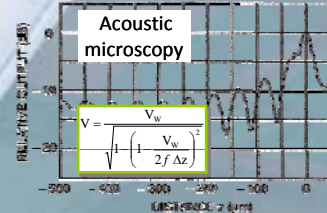
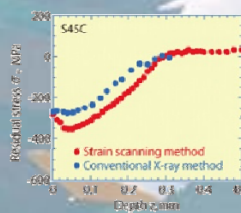
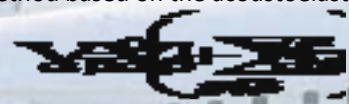
## Non-destructive evaluation of surface stress profile

### Objective

- Ultrasonic measurement of surface residual stresses

### Methodology

- Method based on the acoustoelastic effect
- Requirement for the use of surface wave to measure surface stresses
  - Rayleigh waves (SAW)
  - Leaky Surface Skimming Compressional Wave (LSSCW) also called Critically Refracted Longitudinal Wave ( $L_{CR}$ )
  - Shear Horizontal waves (SH)
- Efficient generation/detection methods
- Extremely accurate velocity measurement
- Immunity to parasitic effects
  - Texture
  - Surface roughness and surface defects
  - Temperature gradient
  - Material inhomogeneity

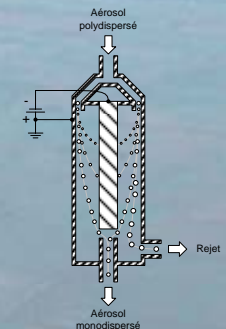


## Development of a portable measuring system for nanoparticles

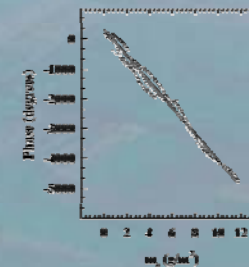
### Objectives

- Through electrical precipitation, nanoparticles classification in terms of electrical mobility
- For every detected class of nanoparticles, an electrometer counts collected particles. An histogram of the amount of particles as a function of their electrical mobility could thus be produced
- For every detected class of nanoparticles, an ultrasonic microbalance evaluates the mass of the collected particles. An histogram of the mass of particles as a function of their electrical mobility could thus be produced

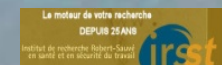
### Particles classification in terms of electrical mobility (FMPS)

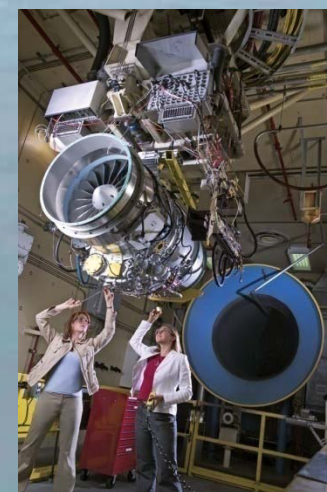
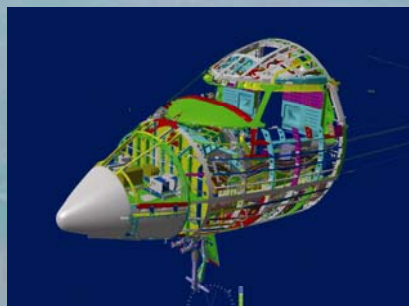
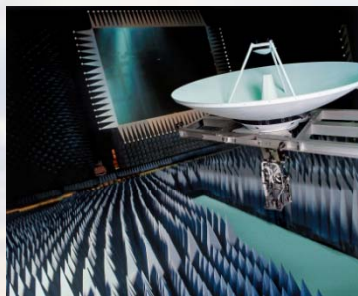


### Acoustical fibre acting as an extremely sensitive ultrasonic microbalance



$$S_m^V = \lim_{\Delta m_s \rightarrow 0} \frac{1}{V_0} \frac{\Delta V}{\Delta m_s} = \frac{-1}{\rho \cdot a}$$





**Questions ?**