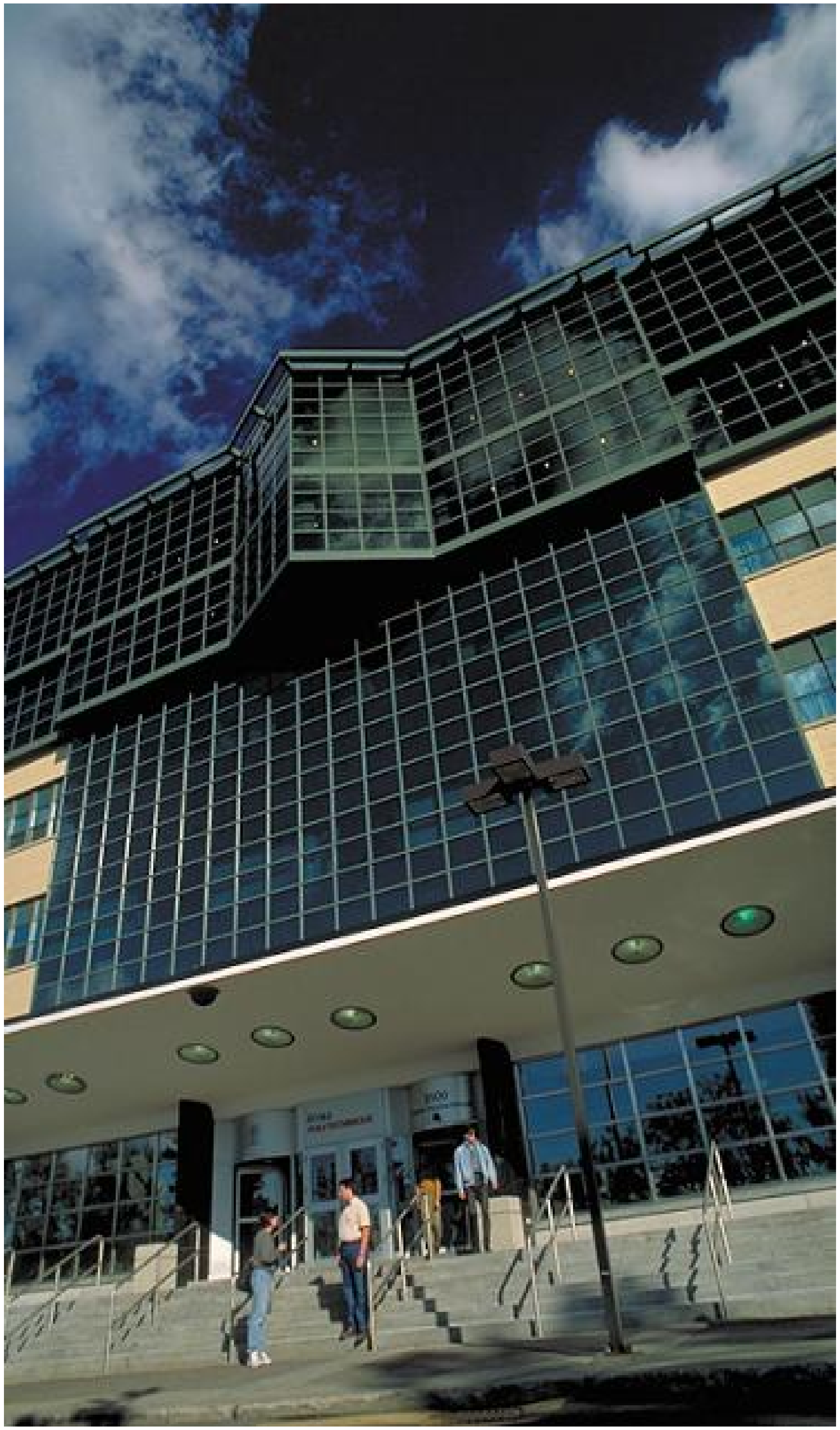
ÉCOLE
POLYTECHNIQUE
MONTRÉAL

Meeting of the NSERC Design Chairs

Robert L. Papineau, Director General

January 19, 2004



Special thanks to our contributors*:*

- Ricardo Camarero, Department of Mechanical Engineering
- Paul Stuart, Department of Chemical Engineering
- Diane Riopel, Alain Aubertin, Departement of Mathematics and Industrial Engineering

Thanks also to:

- Marie-Hélène Dupuis, Library
- Michel Perrier, Department of Chemical Engineering
- Annie Touchette, Constance Forest, Communications Office

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Presentation overview

- Introducing École Polytechnique
- The importance of design in engineering

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Polytechnique

- School affiliated with the Université de Montréal
- Has its own Board of Governors
- École Polytechnique, Université de Montréal and HEC Montréal combined form the second-largest university complex in Canada

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Some statistics

- 5,548 students (fall 2003)
  - 3,634 undergraduates
  - 428 students in continuing education
  - 1,483 masters and doctoral students
- 900 graduates per year
- 220 professors
- 800 employees
- $75M operating budget
- $32M in research funds
- $107M infrastructure fund (CFI) (to date)
- 130-year history
- Total of 20,000 graduates

Engineering programs

- Civil
- Chemical
- Electrical
- Geological

- Industrial
- Computer
- Software

- Mechanical
- Mining
- Physics
- Materials



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Research

- $32M in research funds
- 33 CFI/MEQ projects totalling $107M (to date)
- 17 industrial chairs
- 24 Canada Research Chairs, 17 of which have been attributed to date
- 10 strategic FQRNT professor-researchers

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Research

Direction or involvement in major Valorisation-Recherche Québec projects

- *Développement, intégration et évaluation des technologies de formation et d'apprentissage (DIVA) [development, integration and evaluation of training and learning technologies]*
- *Centre interuniversitaire de référence sur l'analyse, l'interprétation et la gestion du cycle de vie des produits, procédés et services (CIRAIG) [interuniversity reference centre for the life-cycle assessment, interpretation and management of products, processes and services]*
- *Nano-Québec*
- *PROMPT-Québec (wireless communications and photonics)*
- *Consortium for Research and Innovation in Aerospace in Québec (CRIAQ), etc.*

Seven major development areas for Polytechnique

- Multimedia, computer sciences and telecommunications
- Biomedical sciences and engineering
- Advanced materials, nanosciences and nanotechnologies
- Environment, sustainable development and business strategies
- High-end technology for the manufacturing and aerospace industries
- Education technologies for the sciences and engineering
- Science and systems engineering

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Univalor

Mission: to market the results of research conducted by École Polytechnique, HEC Montréal, Université de Montréal and affiliated teaching hospitals

- 10 active spin-off companies
- 21 technology transfers and licensing in effect
- $175M invested in private spin-off companies since 1998
- 250 jobs created in the high-tech industry in the Montréal region
- Approximately $1.5M worth of research contracts granted annually to Polytechnique by its spin-off companies

Polyvalor

Active spin-off companies

- BioSyntech Inc.
- Cardianove Inc.
- LTRIM Technologies Inc.
- Polyplan Technologies Inc.
- Phytobiotech Inc.
- Odotech Inc.
- Nova Plasma Inc.
- Cerestech Inc.
- Sign@metric Inc.

Student life

Technical aspect

- Race car (SAE formula)
- SAE Avion-Cargo
- Solar Vehicle (Esteban)
- All-terrain vehicle (SAE Mini-Baja)
- Human-powered submarine (Archimède)
- Walking and roller robots (SAE Robotics)
- Soccer-playing robots (Robofoot Group)

Cultural and international aspect

- Polytechnique Engineers Without Borders
- Comité international de projets outre-mer (CIPO)
- Poly-Théâtre, Poly-Party, Poly-Rad, Poly-Show, Poly-Photo, etc.

Polytechnique is expanding quickly

Pierre-Lassonde

and Claudette-MacKay-Lassonde Buildings

Expansion: lecture halls, computerized teaching laboratories, library, IT department, electrical and computer engineering departments

Polytechnique is expanding quickly

J.-A.-Bombardier Building

Interdisciplinary research: nanotechnology, biotechnology, aeronautics, aerospace and new materials

Project carried out in conjunction with Université de Montréal

Polytechnique is expanding quickly

Hydro-Québec structural research laboratory

A research laboratory focusing on the structural behaviour of major civil engineering structures

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Polytechnique is expanding quickly

Aerospace Manufacturing Technology Center (AMTC)

National Research Council of Canada laboratory

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A promising future

The importance of design in engineering

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Design is the essence of engineering. Theodore von Karman (1881-1963) said, “A scientist discovers that which exists. An engineer creates that which never was.”

P.C. Wankat et al, The Scholarship of Teaching and Learning in Engineering, p. 3.

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More definitions

“Engineering design integrates mathematics, basic sciences, engineering sciences and complementary studies in developing elements, systems and process to meet specific needs.

It is a creative, iterative and often open-ended process subject to constraints which may be governed by standards or legislation to varying degrees depending upon the discipline.

These constraints may relate to economic, health, safety, environmental, social or other pertinent interdisciplinary factors.”

- *Canadian Engineering Accreditation Board (CEAB)*

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More definitions

The Accreditation Board for Engineering and Technology (U.S.) has a similar definition but adds :

“Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation ”

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Design, Research, Engineering and Innovation

- ***Reference: Presentation to NCDEAS by Tom Brzustowski, President NSERC, October 24, 2003, Ottawa***

Research: the process of learning what is not known (by anyone)

Basic research: research with the object of discovery

Project research: research with the object of solving a problem that cannot be solved with existing knowledge

Note: More complete definitions of basic and project research used by NSERC are given in terms of nine attributes: object, context, format, merit, education/training, results, priority, benefits to humanity in the long term, and short-term economic benefits. Basic research and project research differ in each of these attributes.

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Science: the social system that involves three sequential and interrelated activities: ***research*** conducted according to a prescribed method (the scientific method), ***processes for accepting (or not) the results of research as fact***, and finally ***predictions*** based on facts

Engineering: the professional activity of creating artifacts and systems to meet people's material needs, ***with design as the central process, scientific knowledge*** *and* ***economic considerations*** as its essential inputs, and ***public safety*** as its overriding concern

Technology: the ***set of procedures and tools*** that predictably and reproducibly produces a specific desired effect in the material environment

The main form of creative intellectual activity in science is research; it is both research and design in engineering. The context for creative intellectual activity in science is an experiment, and in engineering it is most often a project.

- Reference: Presentation to NCDEAS by Tom Brzustowski, President NSERC, October 24, 2003, Ottawa

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- **Innovation** is the link between research and economic activity

- The definition of innovation most relevant to the activities of NSERC is: ***Innovation is the process of bringing new goods and services to market, or the result of that process***

- ***Commodities*** are products available from many sources with similar functionality and quality. Commodity producers must ***take the price*** offered in the market

- Producers of ***innovations*** can ***set the price*** for their products, with margins high enough to recover the R&D costs and to invest in the R&D for future products

- Innovation is classified in several ways: ***product vs. process, radical vs. incremental, disruptive vs. sustaining***

- There are other important kinds of innovation that are less directly linked to R&D: ***marketing innovation, institutional innovation, complementary innovation***

\- ***Reference: Presentation to NCDEAS by Tom Brzustowski, President NSERC, October 24, 2003, Ottawa***

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What have we established ?

- Design is the essence of engineering
- Design is the central process of engineering
- Design and Innovation are very closely linked
- The Design and Innovation linkage is present whether the innovation stems from project research (reverse engineering) or basic research (forward engineering)

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- **Why is design in engineering important ?**

Design is the essential element of innovation and thus the creation of economic activity

- **Why is it even more important in Canada ?**

- In Canada, relatively little research is conducted in industry. In the U.S., 70 % of researchers (750,000) work in 15,000 corporate labs (*Ref: Robert Buderi, Engines of Tomorrow)*

- We have no Fraunhofer (Germany) or Battelle (U.S.) or ITRI (Taiwan).
  Ref: Tom Brzustowski's presentation

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What does that situation imply ?

- Strong technical universities in Canada should evolve into more project type research and to more towards design for innovation

- This should translate into the programs offered by universities in technical sectors, engineering foremost

- Many engineering programs stress the acquisition of knowledge to a point where little is left for design education with open-ended problems, multidisciplinary problem-based learning and integration projects

Engineering design training

Diversity of approaches at Polytechnique

3 examples

- ***Industrial engineering***
- ***Chemical engineering***
- ***Mechanical engineering***

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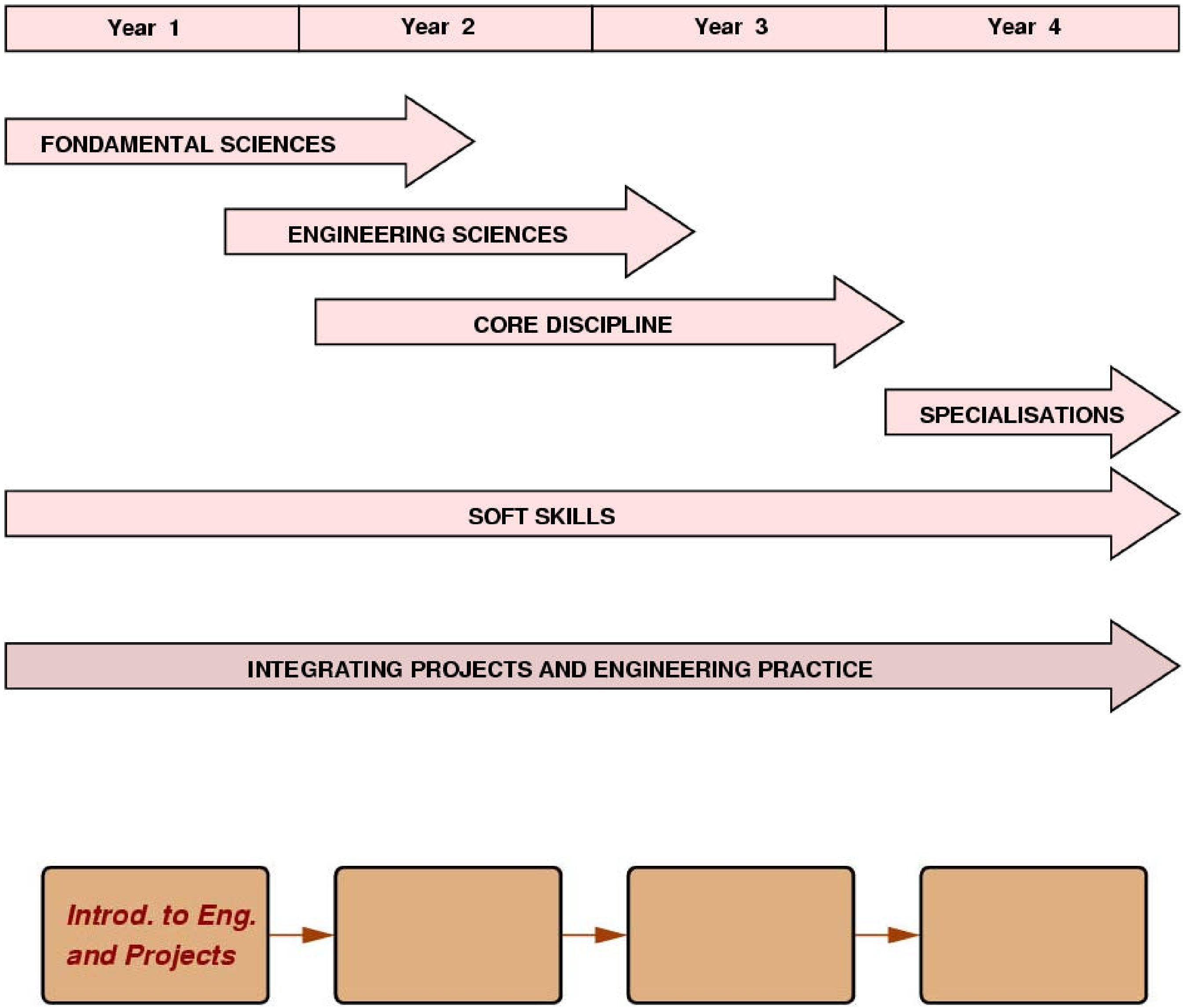
Engineering Design Training

The expectations from a university training in design are numerous and diverse. It is generally recognized that design is not "taught" but "practised". Furthermore, this instruction should not be confined to one course or project, but rather approached as a continuous educational process and integrated over the duration of the entire curriculum.

At Polytechnique, we have implemented this approach by the requirement that each engineering program contain one project for each year of the curriculum with the objective of integrating the acquisition of knowledge with the development of the skills required to practice the engineering profession.

General curriculum structure



1. Prisme - Industrial Engineering Department

PRISME

(Projet Rationnel d’Intégration de Systèmes Manufacturiers d’Entreprises)

« *Enterprise Manufacturing System Rational Integration Projects* »

What is PRISME?

- Industrial Collaboration Program since 1976
- Consulting Industrial Design Projects realized by teams of advanced students in Industrial Engineering
- Projects integrating knowledge, competences and methods relevent to Industrial Engineering Program:
  - Equipment and System Design, Manufacturing Management, Logistic System Design and Planning, Layout Design, Operations Optimization, Quality Engineering, Supply Chain System Design, Manufacturing Processes, Automation, Information System Design, Change Management, etc.
- Real industrial learning context for students
- 10 projects per year (248 projects with 1493 students since 1976)
- 2 professors dedicated full-time to the program

PRISME - for Who?

- SME and large corporations:
  - cost $4000, with 50% financial support for SME through IMPACT PME program (Ministère pour le développement économique régional du Québec)
  - New corporations and new projects every year
- Advanced students enrolled in Industrial Engineering Program: year 4
- Duration: from September to April, 4 cr. Course
- Team of 5 students/project
- Student's involvement:
  - More than 1000 hours of work
  - Weekly meetings with industrial representatives and staff
  - Bi-weekly follow-up with professors Diane Riopel and André Langevin

PRISME – Learning Context

- Application of theoretical approaches and methods to real industrial design problems; interactions with people in the organizations
- Team work
- Consulting approach
- Project Management: planning, progress reporting, coordination, risk management, etc
- Focus on integration of knowledge through an engineering systematic approach: resources, materials, infrastructure, human resources, finance, etc.

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PRISME – Examples of projects

- Plant Design for Wood Machining Equipement Manufacturing; Poitras et Fils Ltée
- Plant and Warehouse Design; Hewitt Equipment
- Design of Control Deck Assembling Unit; CAE
- Improvement of Management and Manufacturing Processes; Systèmes Norbeck
- Growth Plan for Industrial Vehicle Manufacturing; Bombardier
- Design Scenarios for Distribution System and Warehouse Location; L'Oréal

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2. Design Sequence in the Chemical Engineering Department

- Existing Capstone Design Sequence in 4th year:
  - To be presented by Professor Robert Legros on Day 2 of meeting
- Proposed new 12-credit design-based course in 3rd year, related to CDEN initiative:
  - To be presented by Professor Michel Perrier on Day 2 of meeting

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Chemical Engineering Capstone Design Sequence: Today

- GCH4120: Process Design
  - Chemical Engineering Design Process
  - Multidisciplinary design aspects
  - Process Integration Concepts
  - Costing and project ROI concepts
  - Environmental, health and safety issues
  - Project Design Tools: MS Projects, ASPEN and HYSYS process simulation tools, FACT thermodynamic software
- GCH4130: Design Project with Industry
  - Consultant-client relationship
  - Open-ended, multidisciplinary problem-solving

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Chemical Engineering Capstone Design Sequence: Characteristics

- Industrial design project: addressed over both courses, GCH4120 and GCH4130
- 8-12 projects per year, groups of 3-5
- Mainly larger enterprises involved, e.g.
  - CEZinc (Noranda): Zinc Refining
  - Abitibi-Consolidated: TMP Plant
  - Barr-Rosin: grain drying
  - Honeywell: Magnesium production
  - AMEC: papermachine design
- And others…, e.g.
  - NRCan-Canmet: energy system design
  - Pyrogenesis: gas purification system

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Capstone Design Sequence at École Polytechnique : Evolution

- Process Design + Design Project now under discussion
- Considering an increase in the credits for Design Project, due to level of effort required for delivering excellence in projects to industry clients
- Increased emphasis on holistic process analysis tools or “process integration”, e.g. process simulation, thermal pinch analysis, controllability analysis
- Increased emphasis on environment and safety
- Decreased emphasis on survey of unit operation design techniques

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Proposed new 12-Credit Design-Based Course in 3rd year

- Polytechnique is currently developing CDEN modules in undergraduate fluid mechanics, heat transfer, separations, process control, process design.

- The CDEN 3-tier structure has been adapted to involve project-based (design) learning of course material.

- The goal of the overall program is to merge 4 three-credit courses into a one-semester course to help students integrate knowledge in the core subjects of chemical engineering in a design context.

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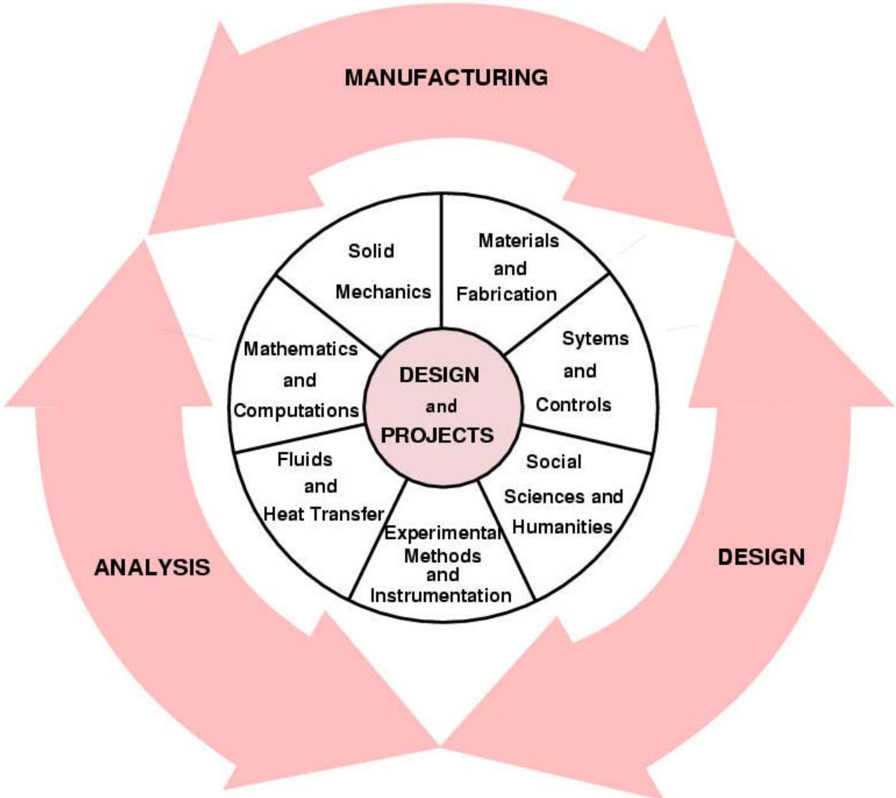
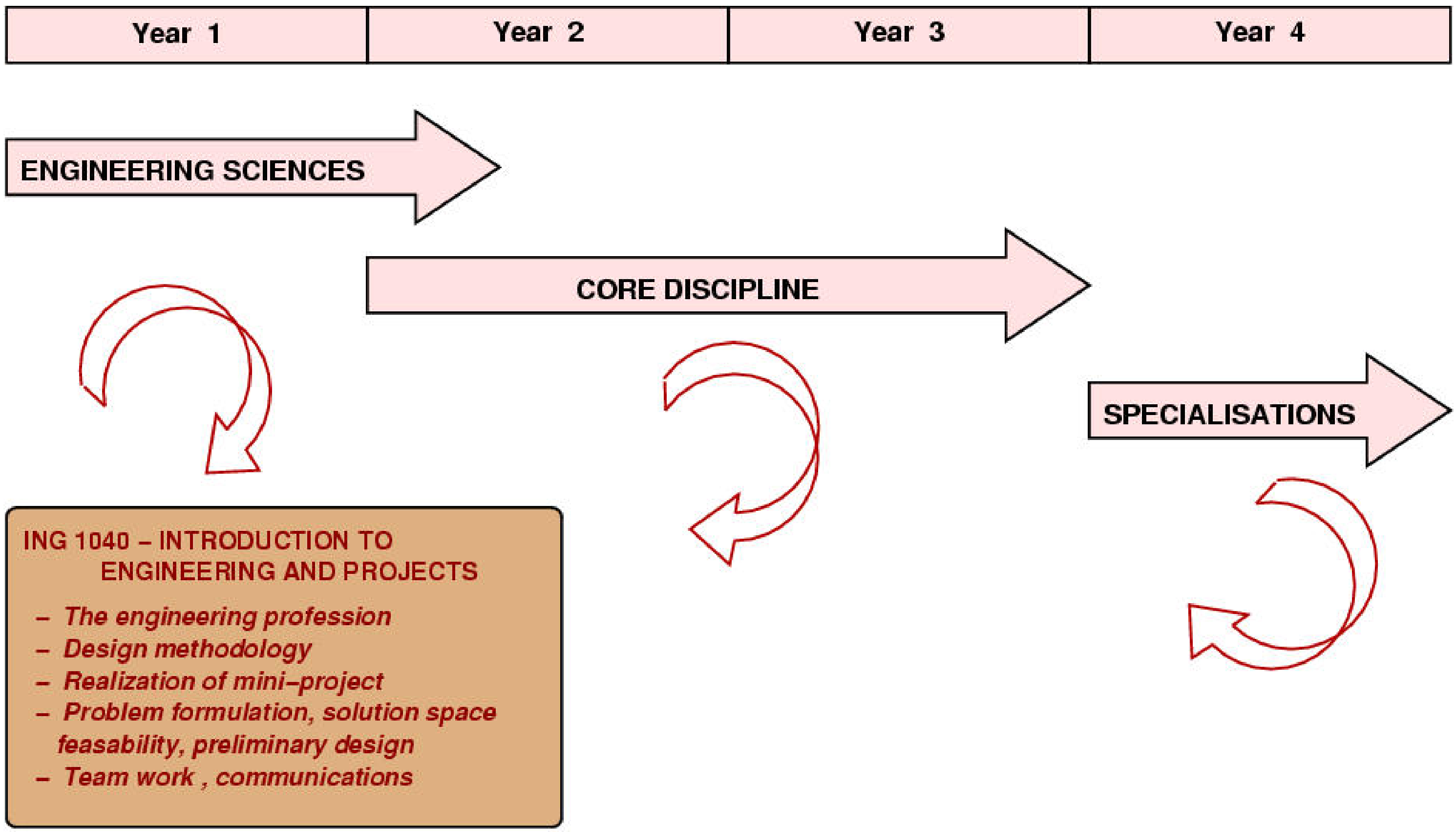
3. Mechanical Engineering Department

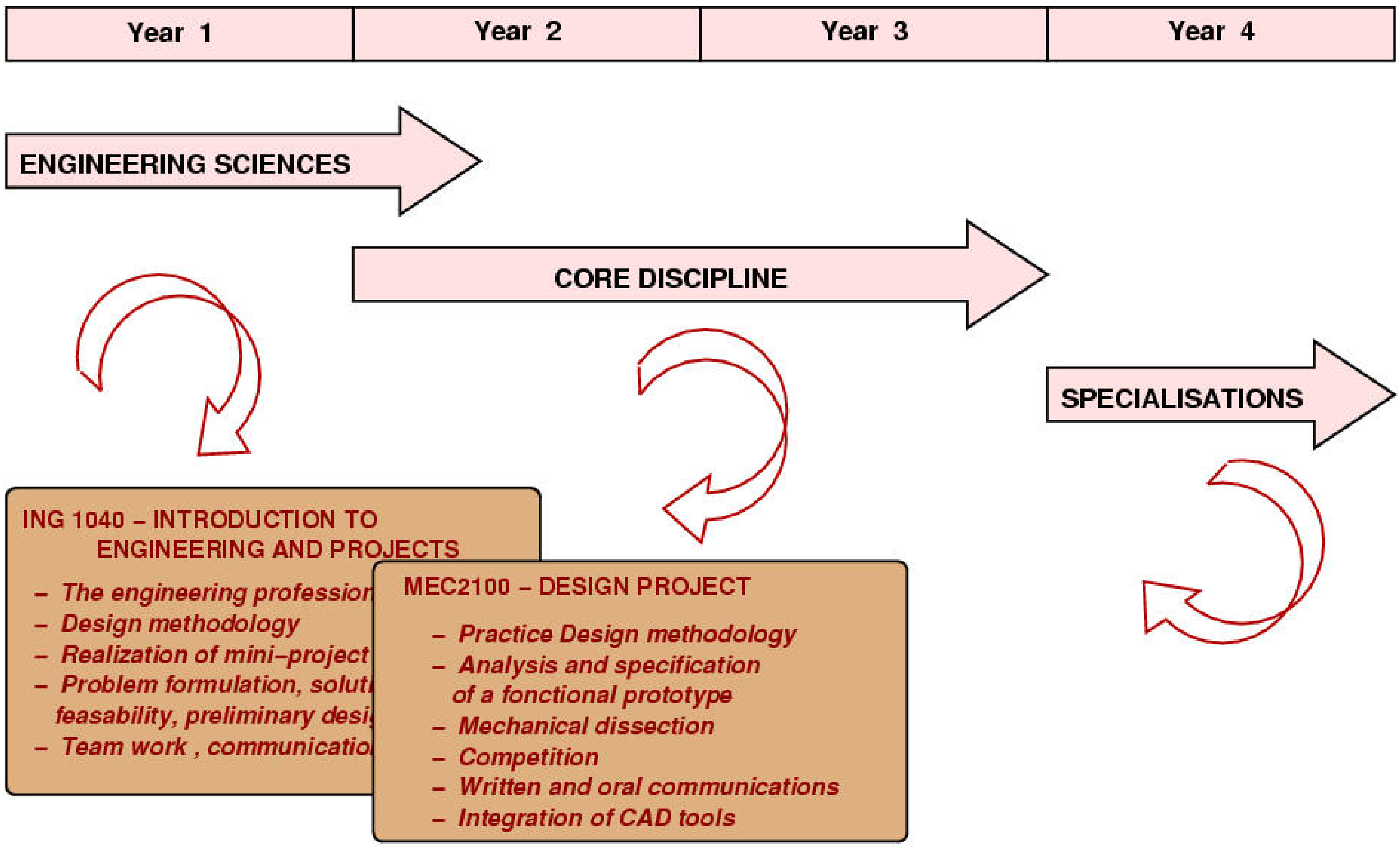
In the mechanical engineering program, the design and project courses constitute the backbone for the integration of knowledge and engineering skills :



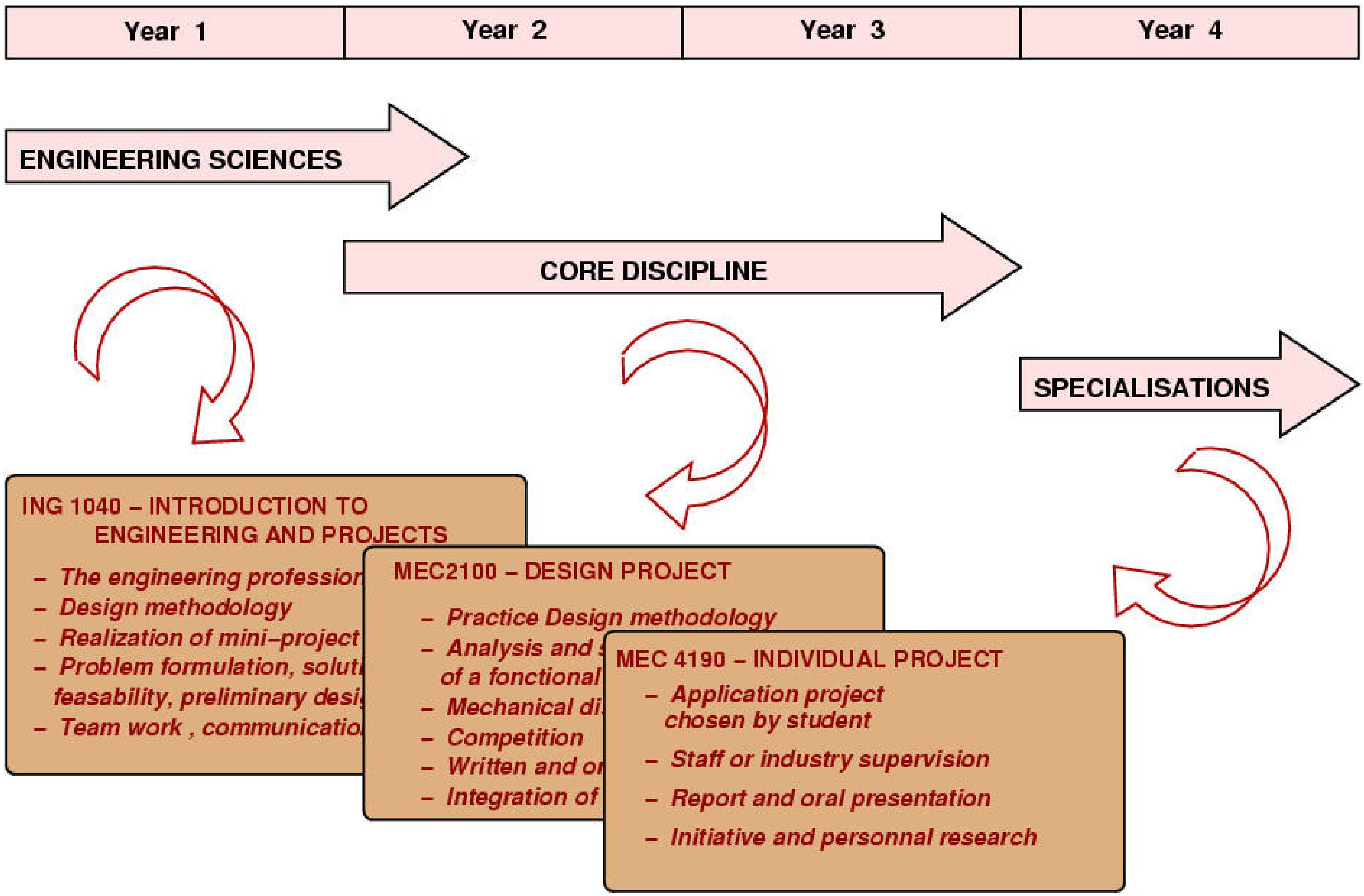
Integrating Projects



Integrating Projects



Integrating Projects



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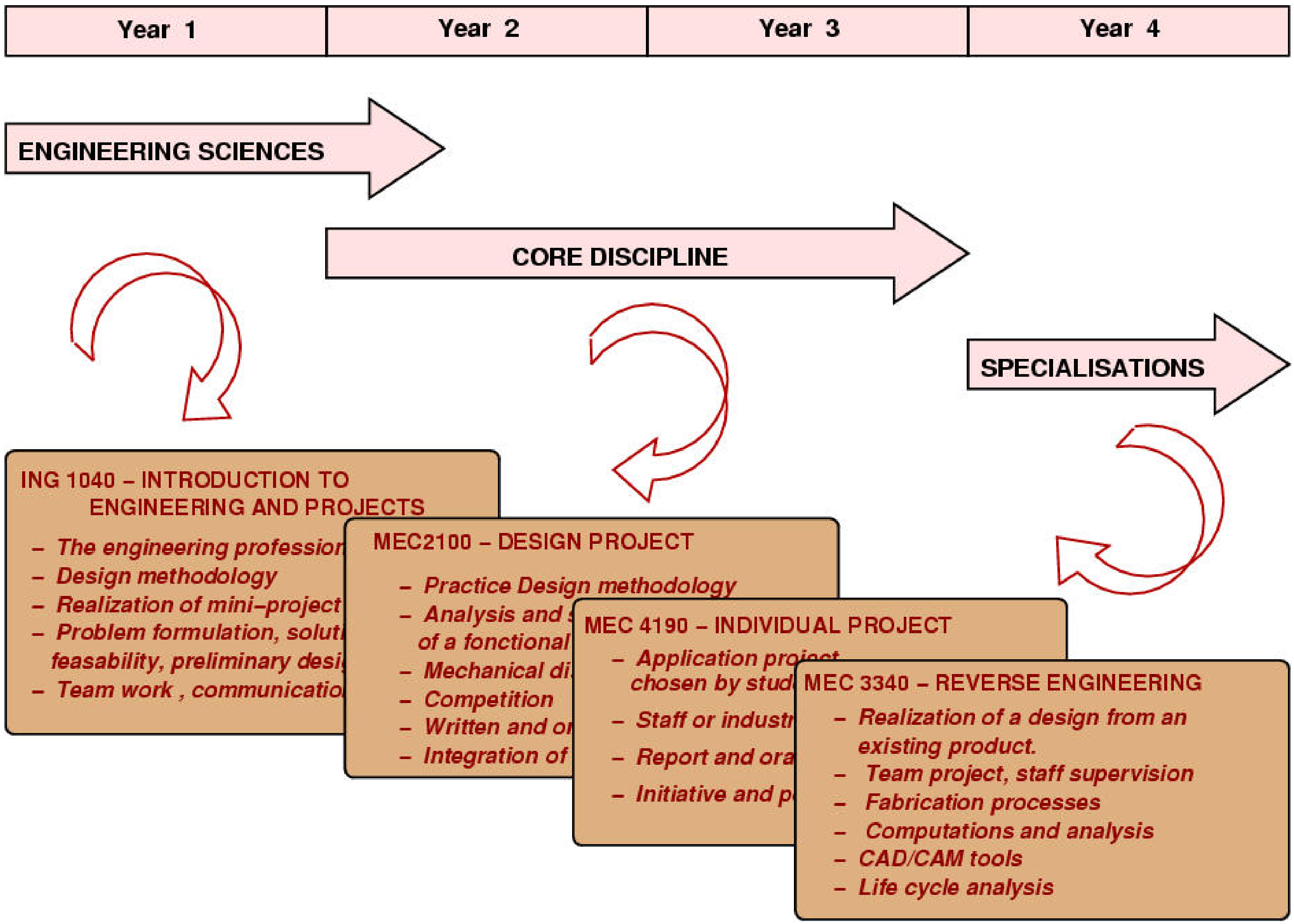
Integrating Projects



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Design in the Master's Program in Aerospace Engineering

In conjunction with CAMAQ, the participating Universities (Concordia, E.T.S., McGill, Laval, Polytechnique and Sherbrooke) offer a joint Master's program in Aerospace Engineering.

École Polytechnique is responsible for the Virtual Environment Option whose goal is to train the next generation of Aerospace Engineers in the most advanced design and analysis methodologies.

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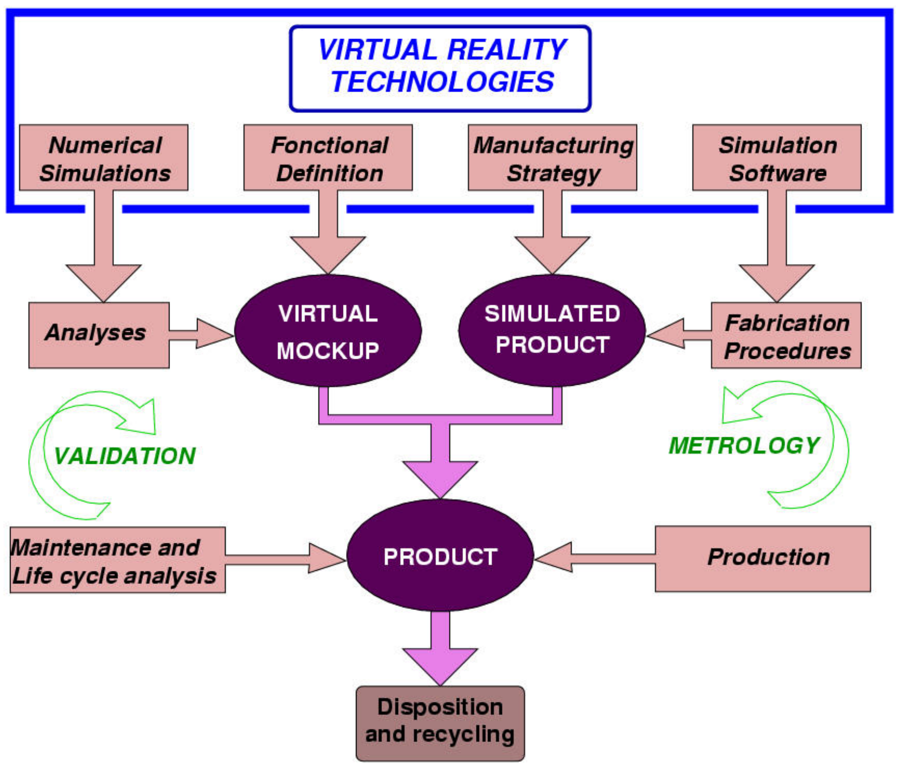
Virtual Environment Option

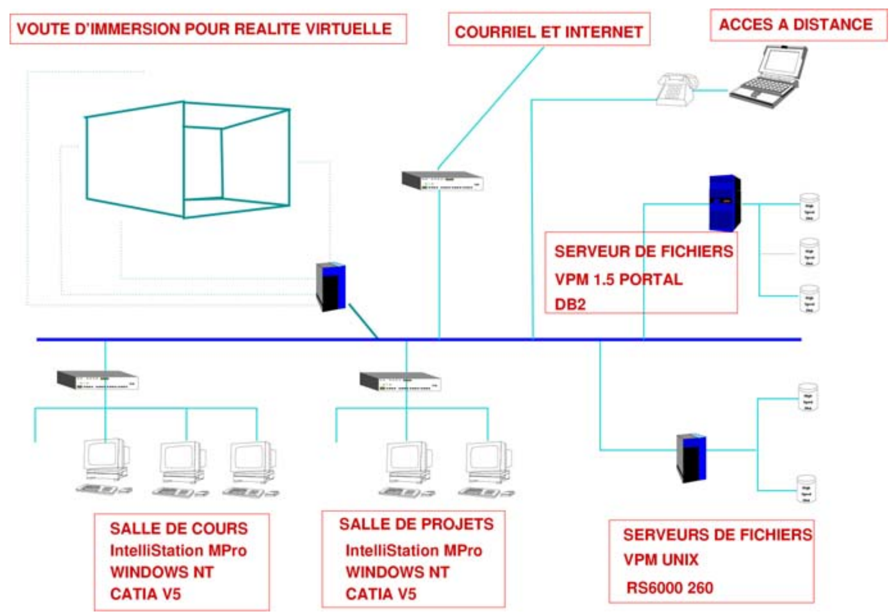
This training is fully supported by industry through courses, internships and case studies.
The objective being to replace traditional design based on empirical and experimental approaches by simulation-based design using the following conceptual model :



Virtual Prototyping

Using a virtual prototyping instructional facility the students are trained to work in a multi-disciplinary environment with collaborators distributed over several sites.

Linked by an high speed network of computers and servers, they collaborate in a given project using advanced modelling and simulation tools based on CATIA, ENOVIA and CATWEB from IBM.



A minor in Virtual Prototyping

After several years of teaching design in this context, we are preparing a minor in the bachelor's program which will be based on the design competition projects in which the technical undergraduate societies participate at the international level (SAE, Mini Baja, Solar Vehicle...).

This will achieve several Objectives :

- integration of extracurricular activities and formal educational process
- facilitate the supervision and implication of faculty members in these activities
- support the students in their chosen projects and increase their motivation

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