# CONTENTS

## INTRODUCTION
Laboratoire de la production d’architecture  3

## DIGITAL PRODUCTION
- Research methodology  5
- Teaching methodology  7

## PROJECTS
- Learning Center Hoarding Piccard  11
- ALB Pavilion  13
- Learning Center Hoarding Esplanade  15
- Fantastic Form  17
- Data:Design  19
- Constructo Cube  21

## LAPA LAB
- MAKA MM7S - 5 Axis CNC Milling  25
- OMAX 5555 - Waterjet Cutting  27
- TR0TEC 5500 - Laser Cutting  29
- FORMECH 1372 - Vacuum Forming  31
- SCHAUBLIN CNC 60 - 4 Axis Metal Milling  33
- Credits  35
INTRODUCTION
LABORATOIRE DE LA PRODUCTION D’ARCHITECTURE

The Laboratoire de la production d’architecture (lapa) was founded in 2005 by Professor Harry Gugger as a research and design laboratory within the school of architecture at the École polytechnique fédérale de Lausanne (EPFL) in Switzerland.

The name of the laboratory indicates this is a lab devoted to the study and research of creating architecture and a place where architecture is produced. The term ‘production’ underscores our view of our built environment as an intellectual, crafted, machine-made and artistic product. When we speak of architecture we imply the entire life cycle of a project: from development, planning and construction to the long term use and existence of the building. This comprehensive approach is also rendered by the word ‘production’ since it designates both the creation of an intellectual commodity and the manufacturing of the product.
DIGITAL PRODUCTION
RESEARCH

lapa is committed to the study and research of architectural production. It is the primary goal of lapa to ensure the architect’s continued role in the building process and to reinforce the architect’s position as a central and coordinating force. Research at lapa therefore aims to improve the understanding of the architectural process.

Issues that affect an architectural project can be both general for the project type or specific to the location or project context. lapa research is devoted to addressing, understanding, and mapping the parameters that affect the success of architectural projects. Following the methodology of teaching, research addresses issues of interdisciplinary collaboration, environmental life cycle issues, and the rationalization of production.

Specific research is also conducted on the implementation of new technologies within architectural production. The objective of this research is to expand the architect’s sphere of influence through the logical and consistent application of digital technology to the entire architectural process.

This focus on new technologies such as generative CAD and computer controlled fabrication emphasises the concept of “the digital chain” - the coordinated flow of data through all the different stages of an architectural project.

The implementation of research into architectural production is the “proof of concept” for lapa. As such research includes the act of creating architecture, both in the experimental context of the university, and the professional context of projects. Informations acquired from built projects and interactions with partner industries allow for conclusions to be drawn about the fabrication processes, as well as the overall life cycle of a project or building.

Through the research of the factors of architectural production lapa seeks to find the ideal environment and processes to ensure the highest possible quality of building.

Programmed pixel motifs: R. Loveridge
Teaching at lapa has two interrelated goals and occurs in two different fields:

Design Studio, where lapa offers the comprehensive teaching of skills associated with the practice of design at the urban and architectural scales. The goal of the studio is to prepare architects for the demands of professional practice.

Digital Design + Production is the lapa “Unité d’Enseignement”, which focuses on the teaching of skills and experimentation with digital tools. The goal of DD+P is to give students experience and insight into advanced technologies, and provide “hands on experience” of building design and construction at the 1:1 scale.

The lapa lab is the research workshop for the Digital Design + Production course, and is a production resource for model and prototype making in the lapa studio.

The overall strategy for teaching at lapa is to show students that the role of the architect is not limited to the planning and design of the building, but rather that the architect is the producer and coordinator of the entire architectural process. To achieve this lapa teaching emphasizes four fundamental beliefs:

- Architects must be capable of working within an interdisciplinary process where collaboration is a fundamental constituent of the architect’s working method.
- The basis of an architectural project is the development of a “functional brief” and the evaluation of its overall feasibility within the different scopes of context.
- Architects must study the technologies that influence the design and fabrication processes. Digital data, generated in the design processes is a valuable commodity and architects must develop and promote the potential of an unbroken “digital chain” from concept to construction.
- Finally, architects must understand the life cycle and impact of their work; that the maintenance, operation and demolition/recycling of a building pose architectural problems, which must already be addressed in the conceptual phase of a project.

Assembly of Alucobond Pavilion. photo R. Loveridge
**Proof of concept**

Projects conducted in the lapa lab may be the final output from a course, may be a proof for design and production research, or may be a collaborative development project with outside industry or other research group.

Projects are always conceived at the 1:1 scale, with the intention of engaging the actual materials and assembly processes. This engagement with materiality, the design of connections, and having to deal with construction issues, gives credibility to the design and designer when engaging with industry.

The use of actual construction materials also gives lapa the opportunity to work together with material engineers, suppliers, and construction specialists from industry.

The Digital Design and Production (DD+P) course develops projects either at the architectural scale – for group projects, or at the human scale - for individual projects. Group projects are aimed at speed of design and production, with results typically aiming at the pavilion, wall or interior design sizes. Individual projects may be furniture, full scale architectural mock-ups, or large scale detail models.

**Collaborations**

Collaboration is a large motivator for the development of projects in the lapa lab. By working with other research groups lapa is introduced to advanced concepts of science, engineering, materiality, and also to functional requirements for design that extend beyond the norm for architecture.

The lapa lab has collaborated with groups such as:
- iBois - Wood Engineering lab
- CCLab - Composite Structures lab
- LCH - Hydraulics lab
- LESO - Solar Building lab
- ICOM - Steel Structures lab
- iMAC - Applied computing lab
- LGG - Computer Geometry lab
- LTC - Composite and Polymer lab
- Archizoom - EPFL exhibition space
- Alcan Innovation Cells - Aluminium
- Studer Handels AG - building materials
Milling patterns from image pixels

The Learning Center hoarding project was the first attempt in the lapa lab at connecting the computer programming of design with the computer control of CNC cutting. For this project images were used as the "input" in a CAD program to create cutting patterns, that would be cut by the CNC milling machine. The first version related the size of round holes to the grey scale values of pixels in an image.

The size and density of the pixels were parametrically controlled. More pixels gave a better resolution to the image, but also took much more time to fabricate. The result is a balance between design intentions and fabrication efficiency. The image chosen for the hoarding was a "curtain" with the EPFL project name, and a plan of the Learning Centre. The curtain was used to represent the idea of "Opening Soon".

Details:
- Size: 24m x 3.4m
- Material: Plastic (white) coated fir plywood

Installed:

Team:
Russell Loveridge, Francois Perrin, Thomas Bregman, Mitch Heynick
Folded composite aluminium shell
With gracious sponsorship from Alcan Composites Switzerland, the chosen material for the project was Alucobond composite panels. This façade sheet material is comprised of an inner core of PE plastic sandwiched by two thin sheets of aluminium. The material thickness is a total of 4mm. This composite configurations allowed the participants to use the CNC milling machine to “cut” or “rout” the panels, so as to create precise folding and assembly patterns.

The resulting pieces were folded to create an “origami” structural pattern - The Alucobond Pavilion.

This project was supported by the doctoral research of Dr. Hani Buri from the iBois Laboratory at the EPFL.

Details:
• Pavilion Size: 8m x 4.2m x 3.4m
• Material: - Alucobond Composite Aluminium/Plastic sandwich panels + Phenolic coated plywood
• Structure: folded plate shell
• Pieces: 16 shell pieces, folded and assembled in place
• Assembly: Bolted panels.

Participants:
Thomas Austerveil, Nikolaj Friis, Anne-Chantal Rufer, Germain Brisson, Jonathan Montandon, Wynd van der Woude, Victor Løvetand Julebæk
Tutor: Russell Loveridge
Collaboration: The EPFL+ECAL Lab, Dr. Hani Buri, iBois
Sponsors: Alcan Composites Switzerland,
**PROJECT**

Learning Center Hoarding: Esplanade

**Parametric pixels**

The second hoarding for the Learning Center faced on the public concourse of the EPFL Esplanade: The designed surface used an architectural rendering as the image for the programmed design.

A new version of the digital geometry program was used to analyse the image and convert the pixel values into “cutouts” for the milling machine. In this version the cutouts were no longer round, but were all different shapes for the pixels and the differences were parametrically controlled.

The genetic shapes for the cutouts were taken from the motifs of the Learning Center design: The single arch, the double arch, the spiral, and the “squished circle”. Each pixel was scaled, rotated, or skewed parametrically based on the grey value of the pixel in the image.

The resulting panels work at two different scales: From up close the viewer notices the holes and the geometric variation within the pattern. With a bit of distance the pattern organization comes into focus and the image of the Learning Center emerges. The arrow on the corner directed visitors to the construction site office of Losinger.

**Details:**

- Size: 36m x 3.2m + 9m x 3.2m [corner]

**Team:**

Russell Loveridge, Francois Perrin
A mini-cinema for the NIFFF

This project used digital production tools to create a temporary “mini-cinema” for the Centre D’Art Neuchatel (CAN) at the Neuchatel International Fantastic Film Festival (NIFFF).

The spiralling folded walls for the pavilion were designed using parametric programming to allow for fast production using the EPFL’s computer controlled fabrication machines.

The main material for the pavilion was sponsored by Alcan Composites, who encouraged the designers to play with their full range of colours and materials.

Students from the course moved to Neuchatel for one week to assemble and build the pavilion in place, and then stayed to enjoy the festival.

Details:
• Size: 4m x 3.7m x 3.4m
• Panels: 58 composite aluminium - Alucobond
• Fabrication: 3 days
• Construction: 3 days

Participants: Natacha Bauer, Arnaud Bovet, Laura Blosser, Dorothee Fritzsche, Tamara Henry, Emma Jonsson, Vincent Lucas, Katrin Marweld, Leon Meyer, Nina Otren, Raphaël Perrinjaquet, Svend Reymond, Nanna Riise

Tutors: Russell Loveridge, Linus Godet, Henrik Axelsson

Collaboration: The NIFFF, CAN, Local Architects

Sponsors: Alcan Composites Sitzerland, Logitech AG, and Schilliger holz AG
PROJECT
DD+P 10 - Data Design

Increasingly digital data is being used to abstract and represent much of the world that surrounds us. This DD+P course investigated how designers can access this data and use it to drive the designing process and then the fabrication machines in the production process.

Well-designed architecture is a mix of form and function. For architecture to “function” it must meet requirements, respond to external influences, and perform according to expectation. Data which influences an architectural project can come from a variety of sources: the project context; environmental, structural or other performative simulations; or from geometric analysis of the design itself. As digital design programming tools become more complex, they allow for greater opportunity to “tune” a project by implementing this specific digital design information into the parametric code of the design.

By creating a design and prototyping process which includes a “feed-back loop” of data into the design process, the design can be refined and optimized.

The project task for DD+P participants was to use simulation software and geometric programming to develop a parametrically controlled wall system, which respond to its environmental data. Each student developed a wall geometry for their individual studio project, and then built a large scale mock-up prototype.

Participants: Didier Callot, Franck Dal-Zotto, Alexandre Endress, José Pedro Faria Azevedo, Stephane Grandgirard, Vincent Mermod, Mobasher Niqui, Martin Nordah, Hildur Ottósóttir, Julie Riedo, Fanny Sernhede, Toru Wada, Livia Wicki, Linda Wiksten, Martin Wyss

Tutors: Russell Loveridge

Individual studio models developed in the Data:Design course:
Stephane Grandgirard (left), Hildur Ottósóttir, Franck Dal-Zotto, Vincent Mermod (below)
PROJECT
Constructo Cube

An experiment platform for DD+P
The “Constructo Cube” is a teaching and experiment platform that allows for the fast montage of design pieces such that they can be evaluated as architectural prototypes or “mock-ups” at the 1:1 scale.

The “Constructo Cube” will be used for tests and design experiments focusing on:
- facade systems and panelization
- walls, ornaments and surface textures.
- roofs and ceiling concepts
- the cube can be made into a “room” to mock-up interior design concepts.
- It can be a basis for future pavilion and small scale structure design projects.

For the first project, the Constructo Cube was used as a demonstration platform for the EPFL open house. During the open house visitors were invited to make “Facade panels” as mini experiments with the digital production technologies. Each facade panel was installed into the frame of the cube, and the resulting custom facade was built up over the two days of the open house.

Details:
- Aluminium extrusions: 90 x 90 x 3000 mm
- Cube form: 12 structural sections + CNC fabricated corners
- Cube size: 3000x3000x3000 mm
- 144 vac formed facade panels

Engagement and collaboration with industry is an important issue for teaching and research in lapa and at the EPFL. The Constructo Cube is the third main collaborative project between Alcan Rio-Tinto and the lapa.

Sponsors:
Alcan Innovation Cells, Alcan Engineered Products, Switzerland.
Mandate

lapa maintains the belief that "hands-on" experience with machines and materials enables better design. With this as a mandate, the lapa lab was conceived as a workshop that allows researchers direct access and experience with production processes.

The goal of the lapa lab is to engage the designers directly in the larger scope of their project, from conception, through prototyping, to final production. Better understanding of the project parameters allows for optimization and "tuning" of the final design and production process.

The equipment in the lab was selected to provide a flexibility of working with different materials. Although lapa engages design at a wide range of scales the machines in the lapa lab are all sized to enable specific focus on typical construction materials used in architecture.

Machines:
The choice of equipment in the lapa lab reflects a commitment to engage with existing industry.

- 5 Axis CNC Milling - MAKA MM7S
- Waterjet Cutting -OMAX 5555
- Laser Cutting - TROTEC S500
- Vacuum Forming - FORMECH 1372
- Metal CNC Milling -SCHAUBLIN CNC 60

The machines of the lapa lab are all "normal" commercial production machines. As such, the lapa lab has an excellent ability to transfer its experimental design and production work into the real commercial world.

Capabilities

The combination of skilled researchers, technicians, wider access to traditional (manual) fabrication equipment, and the well developed infrastructure at the EPFL all bring great potential for experimentation with digital design and production methods.

Although the work and experiments in the lapa lab focus on innovative use of the tools and equipment, the focus of research remains on improving the value of design, and the overall goal of creating excellence in architecture.
The MAKA MM7S is a light industrial 5 Axis milling machine. It can be used for all materials that do not require liquid cooling during the milling process.

The milling machine has 3 axis of movement (X, Y, Z) and 2 axis of rotation (A & B). This means that the cutting head to be positioned robotically in almost any direction or position. This movement allows for very precise sculpting of complex surfaces, and cutting of irregular shape parts.

Cutting or routing is made with a milling tool. Tools may have different profiles and end conditions to allow for different types of cuts. For cutting rounded surfaces “ball mills” are used, for cutting flat surfaces or straight lines, “end mills” are used. The method of fabricating a piece depends on understanding of the digital design, the machining code for the machine, and the cutting tools used for the job.

The machine cutting movements are controlled by a CNC controller. The data for the CNC is generated directly from the digital models designed in the computer by architects and engineers.

Specifications:
- Machine Size:
  - 5 Axis: 1.5m x 2.5m x 0.7m - Rot: A:360° , B: 220°
  - 3 Axis - 1.8m x 3.2m x 0.85m
- Spindle Speed: 24,000 RMP
- Machine Speed: 24,000 mm/min
- Vacuum table: Vacuum “hold down” for large pieces and custom holders
- Tool Changer: 10 tool - in machine
- Tools: Milling, routing, sawing, and engraving tools.

More information:
MAKA - Max Mayer Maschinenbau GmbH.
http://www.maka.com
EQUIPMENT
OMAX 5555 - Waterjet cutter

A water jet cutter is capable of slicing materials using a very fine jet of water or a mixture of water and an abrasive at an extremely high velocity and pressure.

Waterjet cutting is often used for fabrication of very hard or durable materials. It is the preferred method of cutting when the materials are sensitive to temperature change. Waterjet cutting is also used to process materials that resist laser or plasma cutting such as glass, carbon fiber or minerals.

This form of cutting is used in a diverse number of industries from mining and rock cutting to aerospace, and architectural production.

Typical materials:
- Aluminum, steel, or other alloys
- Ceramics, and glass
- Stone, marble, concrete
- Plastics, acrylic, plexiglass
- Foam, synthetics, rubber
- Composites + engineered materials

Specifications:
- Cutting Size: 1,400mm x 1,400mm
- Table Size: 1,600mm x 2,100mm
- Pump Power: 30 HP
- Nozzle Pressure: 40,000 psi (~3,000 bar)

More information:
Distributor for Switzerland: SEM Automation FR.
OMAX Waterjet cutting systems:
http://www.omax.com/
The Trotec Speedy 500 laser cutter is used for scaled prototyping, and for making architectural models. This type of machine is used extensively in the sign making and engraving industries, and has only recently become much more available for architects and model builders.

Cutting with a laser uses focused light to “burn” through the material in a tightly controlled beam. The laser can cut most modeling materials to a thickness of 15mm.

**Typical materials:**
- Carton and paper products
- Thin wood (MDF, veneer, solid wood)
- Plastics, acrylic, plexiglass

**Specifications:**
- Cutting Size: 1,250 x 750 mm
- Laser Power: 120 W
- Laser Type: Sealed CO2 laser
- Vacuum, latt, and honeycomb tables

**More information:**
Distributor Switzerland: IGEPA ADOC S.A.
http://www.adoc.ch
Trotec Laser systems:
http://www.troteclaser.com
Plastic forming allows for the production of many inexpensive pieces from a single mould. A mould is made by CNC milling a basic form into a resilient material. Then the machine is used to heat plastic to the point where it is malleable. Once soft it is stretched and formed over the mould by force of vacuum pressure.

Vacu-forming machines are used mostly in the plastics and packaging industries.

For architectural production this is an interesting technology as it allows for the creation of repetitive panels and pieces. Panelization in architecture is used in all parts of the building such as facades, walls, ceilings and floors. The vacuum former can also be used to form plastic for models, and smaller scale architectural applications.

**Typical materials:**
- Plexiglass and acrylics
- Polyethylene
- PET
- Other thermoformable plastics.
- Special aluminium alloys

**Specifications:**
- Forming Size: 1400 x 700 mm
- Heating units: 18 zone ceramic heaters
- Vacuum pressure: 5 Bar

**More information:**
Formech systems: [http://www.formech.com](http://www.formech.com)
The vertical milling center is a closed "object" scale milling machine intended for milling of metals, composites, and other very hard materials. The fact that the machine is closed allows for the use of cooling fluid to be used (called flooding) in the machining of the part. These types of machines are used extensively in the fabrication of mechanical parts, mass production moulds, and parts for heavy engineering applications.

This machine extends the material palate at the Lapa lab, to include many materials that are commonly employed in "real" architecture, but are not very often machine-able in a pedagogic or research setting. This machine allows the research in the Lapa lab to engage with materials engineers, civil engineers, and product designers and to work with materials that push the limits of what architecture typically works with.

Typical materials:
- Steel, aluminum, alloys
- Composites and ceramics
- Glass and mineral materials.
- High density plastics.

Specifications:
- Milling volume: 600x540 x 540 mm
- Spindle Speed: 8,000 RMP
- Machine Speed: 12,000 mm/min
- Controller: Fanuc 0i MC
- Optional 4th Axis: detachable
- Accuracy: +/- 0.005 mm

More information:
Schaublin Machines SA: http://www.smsa.ch
The realization of the lapa lab could not have been possible without assistance from our collaborating partners within the EPFL.

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