Wood Architecture Research and Fabrication Centres

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Abstract

This thesis explores architectural wood assemblies and fabrication methods, towards the design of a wood architecture research and fabrication centre, at Laurentian University. During the 19th century timber was the dominant building material used throughout Northern Ontario. The industrial revolution of the 20th century, introduced concrete and steel into the construction industry as fire-resistant alternatives to timber buildings. Due to increased environmental concerns and the advancement of engineering capabilities, wood has re-emerge in the 21st century as a low-carbon alternative to concrete and steel construction. This revolution towards a sustainable building industry is demanding an increased understanding of wood, and its potential within the built environment. This thesis examines academic and industry research facilities experimenting with wood buildings assemblies and robotic manufacturing processes. Design and fabrication research is conducted to develop a new architectural assembly that is applied in a building proposal for a Wood Architecture Research and Fabrication Centre at Laurentian University, in Sudbury, Ontario.

Keywords

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Chapter 1: Introduction

Sudbury is a mining and rail city located approximately 400 km north of Toronto, Ontario. Originally part of the Ojibwa peoples land, English and French settlements were established in the area for fur trading in the 17th century. By the 19th century, the emergence of the logging industry, and the resulting discovery of ore deposits brought large numbers of people to the region. Coinciding with the industrial development of the area, the Canadian Pacific Railway established a train station in the town in 1880.*

In 1887, 376 people resided in Sudbury, and as a result, the first church to serve the community began construction. It took two years for the construction of the Saint Anne des Pins Church to be concluded. The building was appropriately designed to meet the multiple needs of the community. It served as a church, school and parish hall. Due to the availability and workability of timber in the region, the church was constructed of wood and stone, which unfortunately resulted in a fire in March, five years later. A new and smaller church was built in the same year to replace it.² Logically, the buildings at the time were made out of wood, an abundant and easily sourced material, which continued until the end of the century. However, with the development of the industrial revolution, other materials such as steel and reinforced concrete gained prevalence. As a result, for a large part of the 20th century, wood was primarily used for light-wood residential framing and not much else.³ Steel and concrete dominated the construction industries in North America until recently; with rising concerns for climate change wood is re-emerging as the preferred architectural building material.

Ruth Slavid argues in her book *New Wood Architecture*, that timber seems to have re-emerged due to two major factors.⁴ The first is the interest in sustainable building materials due to increasing environmental concerns, since one of the characteristics of the material is its ability to absorb carbon dioxide. In fact, in the United States, its forests make up 90% of its carbon sink.⁵ A tree absorbs roughly half of its own weight in carbon.⁶ Additionally, wood offers low energy requirements to produce it. For comparison, the production of a cubic meter of aluminum requires 1,460 times more energy than is needed to make an identically sized
piece of roughly sawn timber. The second factor to influence the return of wood is the advancement in engineered lumber technologies. With developments such as glulam, cross laminated timber and parallel strand lumber to name a few, designers are capable of creating larger and more complicated mass timber buildings than ever before.

It is fundamentally important for sustainable materials to play a larger role in the built environment today. In his book, Tall Wood Buildings, architect Michael Green stresses the importance of a building industry that is oriented around climate change, our forests and the world’s continuously growing population. According to Green, concrete production is responsible for around 5% to 8% of greenhouse gas emissions globally. Although it is a relatively easy and strong material to work with, it is also playing a tangible role in climate change today. Steel is also proving to be an issue. Its production requires approximately 4% of the world’s energy consumption. These issues highlight the importance of mass timber as an alternative to concrete and steel construction. Mass Timber construction sequesters carbon emissions and can be produced at a large enough scale to reduce global emissions. Technological advancements within the lumber industry along with sustainable forestry practices suggest that timber offers the potential to dramatically reduce carbon emissions produced by the building industry and offer a 'greener' future.

The argument for building with wood is becoming widely accepted within the construction industry today. Architects and engineers have recently produced a number of landmark tall wood buildings such as the Brock Commons in Vancouver, and experimental institutional buildings including the DARE District Building in Ottawa. The limits of timber are being pushed further and further, signifying that a fundamental change in construction is on the verge. One of the key limiting factors in advancing wood applications in the construction industry is the lack of wood research facilities in Universities. Wood research over the last century has trailed behind steel and concrete. Applied research in the areas of emerging wood products, wood structural systems and insulated roof and wall assemblies, along with robotic wood manufacturing techniques, are all essential toward advancing wood as the predominant construction material in the 21st century. Toward this end, a number of institutions, such as the University of Massachusetts, the Architectural Association’s Hooke Park and Princeton University have recently built educational facilities for applied research in wood architecture.
The McEwen School of Architecture at Laurentian University was established in 2013. The School’s curriculum focuses on developing new applications for wood in architectural design. The School’s design-build program provides faculty and students with the opportunity to experiment with building large-scale prototypes of wood structures. Digital fabrication tools such as laser cutters, a CNC and a robotic arm are located within the woodshop. The woodshop facility works acceptably for the production of projects to a maximum size of 5 meters x 5 meters x 2.5 meters. However, the workshop is not adequate for full-sized building construction. Furthermore, with a focus on architecture for a northern climate, it is important to develop a new construction strategy for embracing an environment that fluctuates from extreme cold, to extreme heat. In order to further develop the design-build curriculum with a focus on the north, a larger and more specialised wood research facility is required. This thesis explores architectural wood assemblies and fabrication methods towards the design of a wood architecture research and fabrication centre, at Laurentian University.

Endnotes:

7 Slavid. 2005.
9 Ibid.
Figure 1: Double curving glue laminated beam prototype
1.2 Methodology

This first component of this research project will outline existing wood products used in the construction industry. It will serve to argue that our understanding of timber has advanced through increased materials and design research. A series of six case studies of leading architecture research and fabrication centres are presented in the following chapter. The precedents vary in scale and in research typologies. In order to have a full perspective, these buildings are divided into two sub categories; academia and industry. The academic buildings include the John W. Olver Design Building, the Princeton University Embodied Computation Lab and Hooke Park. On the side of industry, I will look at StructureCraft, Kaufmann Zimmerei and the Autodesk BUILD Space as examples. Throughout these case studies, I will highlight their research, their facilities and tools, as well as the relationship of these factors to the buildings that house them. This approach will provide the in depth understanding of precedents necessary, which will then assist in informing a building design proposal.

In addition, I produced a series of models that explore prefabricated wood assemblies for the building’s design. The prototypes consider transportation restrictions, the many tools available to designers; and that are intended to consider the application of wood with new ideas. This second approach will inform the shape of the building design and proposed construction method.
Chapter 2: Examination of Building Construction Wood Products

The following is an outline of existing wood products used in the construction industry. This analysis illustrates the evolution of our understanding of wood construction and technology, and forest product development over time. The gradual progression from simple dimensional lumber to complex wood assemblies and fabrication processes, demonstrates a history of applied wood research toward new wood building products.

**Dimensional Lumber**

The common 2x4 is a staple product of the construction industry. It is instantly recognizable and available for purchase almost anywhere in North America. Prior to the standardization of dimensional lumber at the end of the 19th century, wood was harvested and milled in the proximity of the building construction site. As a result, timber used for columns, beams, stud walls, rafters, etc. varied in sizes, and carpenters were accustomed to adjusting for the material that they had available. As local forests were clear cut, lumber mills were forced to harvest timber further away from the mill and ship the lumber further distances to construction sites. During this time the size variations among lumber mills became an industry problem and market standardisation was necessary. Market demand for common ‘stick frame’ construction led to structural and milling requirements for standard 2 inch thick dimensional lumber by the beginning of the 20th century.

Contemporary dimensional lumber is not milled exactly to its marketed title. For example, a 2x4 is really 1½ inch x 3½ inch. The ½ inch difference between the nominal and actual dimensions of a 2x4 emerged during the Second World War when wood was in increased demand for the war effort. Additionally, other materials such as concrete blocks, were proving to be a quick and cheap method for erecting buildings. So in order to remain competitive, in 1964, the standard 2x4 shrank half an inch in width and depth, for a 34% reduction in volume. This modification was an economically motivated compromise which remains in place to date.¹
Figure 2: Image of dimensional lumber
Figure 3: Plywood

Figure 4: Medium Density Fibreboard
**Plywood**

Plywood is a highly versatile wood product that can be commonly found in construction projects, furniture, and in vehicles. It is a popular material due to its relatively low cost, its strength, and non-warping characteristics. It is made of multiple layers of thin sheets of wood, glued and pressed into large panels. The wood grain of each of these layers is oriented perpendicularly to its neighbour.

The earliest known applications of plywood date to ancient Egypt. Along with depictions of the material, Egyptians fabricated caskets and furniture with plywood. In the 18th century, it was considered a luxurious material and used in high-end furniture. The mass production and standardization of plywood made it increasingly affordable during the 19th century and started to be used in buildings and everyday objects, including cabinets and tables. During the Second World War, plywood was made with waterproof adhesives and became “essential war material”, and was put under government control. It was used to build a wide variety of objects including vehicles such as lifeboats, gliders, planes, shelters, and other accessories. The demand was so great that approximately 1.2 to 1.8 billion square feet of the material was produced on an annual basis for the United States military. Following the war, the demand for the material continued to grow and production reached 16 billion square feet by 1975. Despite the fact that there are more engineered wood products available today, plywood remains an essential building material within the construction industry. It remains the preferred wood product for floor decking, exterior wall sheathing, roof decking, and numerous furniture and millwork applications.

**Medium Density Fibreboard**

Medium Density Fibreboard (MDF) is a composite sheet product made from compressed recycled wood fibers and resin. The resulting product is strong and resists warping due to the elimination of consistent wood grains. It is a relatively popular material for its versatility, ease of use, and cost. The material property of MDF offers resistance to changes in temperature and humidity. In contrast to solid wood, MDF will generally expand evenly rather than warping, making it an ideal material for doors, cabinetry, furniture, or any other objects that require resistance to shrinking and cracking.
William Mason invented hardboard in 1925, which eventually led to the development of MDF, in the 1960’s. In fact, he created accidentally, while trying to develop a wood based insulation. The material took off, and remains as a popular material to this day. MDF remains a useful product in the modern construction industry, it utilises the discarded material from the fabrication of other wood products in its production and provides an opportunity to totally eliminate waste in wood working facilities and lumber mills.

**Particleboard**

Made from the residual waste from the production of wood products (saw dust, wood shavings or chips), particleboard is a non-structural panel that was created as a by-product to this process. The Recycled wood fibre materials are joined through a similar process to Medium Density Fiberboard. The material is compressed with adhesive resin and heated to create the final board product. Particleboard emerged in the 1940’s as a solution to post war timber shortages. Acting as a secondary material produced from offcuts, planer shaving and any other leftovers from processed lumber. Particleboard is structured in layers; larger and coarser particles are positioned in the centre, while the finer material, such as sawdust, is located at the top and bottom to provide a smooth surface. This construction creates a product that is cost efficient and reasonably strong; therefore, “It is generally used for industrial purposes as a raw material in the production of finished goods, such as ready-to-assemble furniture or cabinets. Particleboard is either hidden from view in a finished product or covered with a decorative coating such as a wood veneer or resin-impregnated paper.”

**Oriented Strand Board**

Oriented Strand Board (OSB) is a structural wood panel that is commonly used as sheathing, roofing and sub-flooring in smaller scale buildings, such as residential projects. Since its strength is comparable to that of plywood, it can also be found in industrial manufacturing of furniture, as a hidden structural component. OSB is comprised of wood strands and chips that are oriented longitudinally in relation to the panel at the surface. In the centre of the panel, dimensional stability is provided by strands oriented in a variety of directions. These wood chips are then pressed and adhered with waterproof glue. This panel construction creates a product that is strong, resistant to deflection and effective in exterior conditions where it may be exposed to moisture. The
Figure 5: Particleboard

Figure 6: Oriented Strand Board
Figure 7: Exposed Glulam beams

Figure 8: LVL beams
fabrication process produces large, continuous mats, which allows for a lot of flexibility in board sizes, ranging in thickness and dimensions. This means that it can be cut in the standard 4’x8’, or in more uncommon sizes such as 8’x24’ panels, for example. Some of the more recent evolutions of the material is its inclusion in engineered wood products, such as pre-fabricated wall components and I-joists. Over the past 25 years, OSB has been gradually replacing plywood in the construction industry. As of 2012, Canada produced approximately 5.2 million cubic meters, of Oriented Strand Lumber, approximately 1/3 of the entire product in North America.

Glue-Laminated Timber

Glue-Laminated Timber (Glulam) is a mass timber product, used as structural beams and columns in projects that vary in scale between the very small to the very large. According to StructureCraft builders, Glulam “has almost the same load bearing capacity as steel, but a far lower weight and excellent fire resistance due to its charring characteristics. When used in heavy timber construction, Glulam ensures high earthquake resistance and excellent resistance to aggressive substances.” Furthermore, the product offers a large amount of design flexibility. It can be fabricated as a straight member, or complex curves can also be introduced. It is fabricated through the lamination of multiple long and thin wood members with parallel running grain. The lumber is adhered with water resistant glue and pressed together to create an incredible strong hold. Curved beams are fabricated in a similar process; the assembly is clamped to hold the desired curve until the glue has dried sufficiently. The fabrication of glulam products requires a high level of precision and quality of material. Therefore certification is required to produce it. “Canadian glulam is manufactured in three species combinations: Douglas Fir-Larch, Hem-Fir and Spruce-Pine”, all of which must be dried to a maximum moisture content of 15%.

Glulam is a versatile product that can work in many different architectural-structural applications. Glulam is often custom made for each unique building project. The product is mainly used to construct roofs and walls.

Laminated Veneer Lumber

Laminated Veneer Lumber (LVL) is an engineered structural product that is similar in construction to plywood. However rather than
to create a panel, LVL is made to act as a beam or joist. It is fabricated with the lamination of thin veneer. In order to utilise the natural strength of wood under a single directional load, all of the grain is oriented longitudinally. This construction allows for forgiveness in failure, related to individual pieces of veneer. Since knots and other deficiencies are minimalized by the slicing process, and since no two pieces are alike, defects are spread around the material for a more even consistency. Like glulam, StructureCraft can customize this product for individual building projects; however they do not fabricate the original LVL material. This also includes panels, which can be made to span up to 60' with a width of 4' and a thickness of up to 11.5". They are able to make such large panels thanks to a joinery system called scarf joining. This is an end to end connection that is achieved by chamfering the joining members, giving them flat, angled faces which can then be glued together.

**Cross Laminated Timber**

Cross Laminated Timber (CLT) is large, solid wood structural panel system that is often used in floor, wall and roof assemblies in mid to large scale building projects. It was “originally invented in the 1970’s, the first industrialised Cross-Laminated Timber manufacturing facilities were established in Europe in the late 1980’s, and are increasingly gaining recognition as a high performance material for structural systems.” Over time, the material has gradually grown in popularity due to its design flexibility, strength, aesthetic and for its use of renewable resources. Its construction is a combination of ideas that resemble dimensional lumber and plywood. Since this is a structural component, it requires a large amount of thickness. Therefore long members of wood that resemble conventional 2x4s’ are glue laminated together, then layered on top of each other perpendicularly for better performing dimensional stability. CLT walls are available with a minimum of 3 layers with a thickness of 4.5” (amount of layers x 1.5”), and can generally be made to have as many as 9 layers for a thickness of 13.5”. Each of these panels can then be made as large as 8’ in width and 64’ in length. This mass timber system is ideal for walls that require loadbearing capacities (without the need for metal reinforcement). Furthermore, CLT panels utilise a prefabrication methodology. This means that it cannot only be made into a simple, solid product, but it can also be specially customised with openings, or have metal connections installed to meet the needs of a specific project. As a result, this facilitates assembly on site, and can therefore reduce construction time significantly.
Figure 9: CLT wall in the McEwen School of Architecture Library
Figure 10: Wood I-Joists installed at a construction site

Figure 11: Parallel Strand Lumber
Wood I-joists

Invented in 1969 by the Trus Joist Corporation, the wood I-joist is an innovative product which outperforms standard lumber in floor construction. They are capable of spanning longer distances, minimising material while also improving stiffness and stability. They’re only real weakness when compared to sawn lumber joists is fire resistance, due to its lack of thickness. I-joists are fabricated with a sawn lumber top and bottom ‘flange’, with a thin plywood or OSB web that connects between the centre’s of the two, which gives it the appearance related to its name. Because of the engineered panel at the centre, directional stability is greatly improved, which can effectively minimises shrinking or warping after installation. This creates a product that is extremely stiff, which can eliminate the ‘creaking’ noises heard in older floors. These characteristics are what made the popularity of this product grow. In the 1970’s, although expensive at the time, wood I-joists offered the potential to have large open floor spaces, a trend that was emerging at the time. I-joists, when compared to normal sawn lumber joists, are stronger, stiffer, lighter and perform more consistently. The product revolutionized the understanding of engineered lumber. It demonstrated that wood could be innovated and rethought, that a plain material could be reassembled in such a way, that it creates something new and better suites its purpose.\(^{22}\)

Parallel Strand Lumber & Laminated Strand Lumber

Parallel Strand Lumber (PSL) is a wood composite material that forms a strong, structural mass timber product. It was developed and patented by Weyerhaeuser, and is marketed as Parallam. It is often used to form beams and columns in larger scale construction. It can also be found in headers and lintels to suit certain needs in a light frame building process. It is fabricated through a process of lamination, similar to OSB or particle board. However rather than using wood chip, long and thin wooden strands (4-8 feet in length) which are parallel to each other.\(^ {23}\) The result is a long and thin member, which is not unlike sawn lumber. Like all other engineered wood products, it is more resistant to warping due to its construction.\(^ {24}\) The major difference being that, since it is reconstructed, defects such as knots are evenly spread out, which results in a more consistent and reliable product.\(^ {25}\)
The aforementioned wood products are among a selection that is available today. Often developed for a specific project, or to fill a gap, that wood may not have traditionally been able to fill; innovative new solutions in wood fabrication emerged. From standardised 2x4’s, to plywood, to parallel strand lumber, wood products are capable of serving most needs in the construction of a building. The existence of all of these wood technologies, and the proof of its evolution, serves as evidence that wood construction has not yet reached its full potential in the construction industry. Facilities that research fabrication, technologies and their relationship to timber is crucial. This will allow the continued development of the material, thus producing a wider variety of products and building systems for architects and engineers to design for the future.

Endnotes:


4 Ibid.


8 Greene 2013


19 Ibid.
25 Parallel Strand Lumber. 2019
Chapter 3: Wood Research Facility Case Studies

Several educational institutions have been instrumental in initiating a shift in the construction industry toward timber construction as a low carbon alternative to conventional steel and concrete buildings systems. A number of these universities have built dedicated research facilities to support advanced research in wood construction and digital fabrication processes. The facilities provide the space and equipment required to produce large-sized prototyping of wood structures in an environmentally controlled space.

Additionally, significant advancements toward new wood building technology have been developed in construction industry workshops and forest product industry supported research laboratories. These commercial facilities are developing and applying their research towards new building products, custom wood building structures and the mass production of prefabricated wood buildings.

The following case studies explore selected academic and industry wood research facilities. The research buildings design and equipment are discussed along with the unique research that is conducted within the facility.
3.1 John W. Olver Design Building

Location: Amherst, Massachusetts  
Architect: Leers Weinzapfel Associates  
Size: 87 000 sq. ft.  
Cost: $57 million  
Complete in: 2017

Introduction

Built in 2017, the John W. Olver Design Building was created to respond to the needs of the Architecture, Landscape Architecture and regional planning, as well as the Building and Construction Technology programs at the University of Massachusetts at Amherst. The building provides students with the resources for material exploration, collaboration, exchanging ideas and experimenting with new technologies.

Figure 12: The main common area of the John W. Olver Design Building is a multi-use space at the core of the building. It provides the space for presentations, lectures, exhibitions and informal gatherings.
Figure 13: CLT column connections at the design building
Project Description

The Design Building is planned around a sunlit central common area for students to gather. Featuring wooden stair bleachers, the space is ideal for presentations, lectures and exhibitions. To the west side of the commons, informal gatherings are encouraged by the lounge/café area, situated next to the large curtainwall. Andrea Leers, a founding member of LWA, describes it as “a three-sided courtyard [that] spills out through the café, through the entryway, down into the main campus, and invites the campus in.”

Enveloping this central space is four floors on the west side, and three on the east, filled with teaching and research areas. On the ground floor, in addition to the commons, it also features labs, fabrication spaces and classrooms. The second floor focuses on workspaces, containing mostly studios and offices. It also holds a small pin-up lounge and the Trimble Technology Lab. The third floor holds more studios and office spaces. This level is also where students and faculty gain access to the green roof. The program for this area is multifaceted, it is a comfortable escape for students, and it also acts as experimentation and learning.
Figure 15: The Zipper Truss cleverly utilises tension and compression to create a unique structure that eliminates the need for columns. It is a piece that not only serves its practical purpose, but equally represents the type of innovative research that is being generated at the school.

Figure 16: Multiple facilities throughout the building provide the tools that allow students to build and test their wood design projects.
environment for the landscape architecture program. Finally, the fourth floor holds an additional studio, as well as a lounge and work space for PhD students.²

The John W. Olver Design Building is a demonstration of sustainable building technologies and advanced wood structures. It is the first and (at the time of completion) largest academic cross laminated timber building in the United States.³ It illustrates that mass timber construction can adopt complex forms and has a place in the large scale building construction. The potential of prefabrication is put on display. With the help of 3D modelling and digital fabrication, the construction site was clean and quiet. Peggi Clouston (a faculty member involved in the design of the building) explains that it also quickened the installation time. For example, within a weekend, “the four 60-foot-tall-by-1-foot-deep CLT panels comprising one of the building’s shear-wall cores were lifted and dropped into place with a crane, and anchored to the foundation”.⁴ This type of construction methodology highlights the incredible potential of prefabrication and engineered mass timber systems. It is an effective and meaningful approach, which promotes the type of research that is being conducted within the Design Building.

Facilities & Tools
The major facilities include:⁵

Wood Mechanics Laboratory:
Established in the 1960’s, the interdisciplinary lab focused on wood adhesives and wood chemistry. Over time, the lab has developed a focus on structural materials, building components, bio based product testing and non-wood products such as bamboo. The following is a list of tools and equipment at the facility:
• 2000 sq. ft. flexible high-head testing and teaching area with strong floor and 5-ton crane
• Large-specimen manufacturing, testing and storage
• 150 kN (33 kip) Material Testing System (MTS) testing machine
• Lunaire 0.9 m³ (32 ft³) steady-state temperature/humidity conditioning and test chamber
• Walk-in conditioning chamber
• Izod impact tester
• Logic Beach hyperlogger 16-channel mobile data logger
• Logic Beach minilogger 4-channel mobile data logger
Figure 17: Mass timber is found throughout the entire building, including the multiple studio spaces.

Figure 18: Workers install a zipper truss, providing a sense of scale to the system.
• IOTech 60-channel data acquisition system
• Drying ovens
• Dry kiln
• MakerBot Replicator 3D printer
• Shopbot Handibot CNC router
• 10’ glulam and CLT press
• Concrete mixer and testing equipment

Building Systems Lab:
The Building Systems lab was designed for graduate level research of building energy performance, building systems and building assessment.
• Building Energy Modeling Computer Station
• Building Products Samples
• Carbon Monoxide Analyzer
• Chilled Beam
• Heat Recovery Ventilator
• Heliodon
• HOBO Data loggers
• Light Meters
• Minneapolis Blower Door
• Minneapolis Duct Blaster
• Moisture Meters
• Non-Contact Thermometers
• Pyranometer
• Radon Detector
• Sling Psychrometer
• Theatrical Fog Machine
• Thermal Imaging Camera
• Wall, Roof, Window Assembly Full Size Mock-ups

Trimble Technology Lab:
Built in collaboration with Trimble Inc. the technology lab provides the software’s and tools required for researching digital fabrication, 3d building models and analysing built environments.
• Laser building scanners
• Imaging rovers
• Global Navigation Satellite System (GNSS) receivers
• Total stations
• Theodolites
• Auto-levels
Research

The Design Building provides several facilities for materials and systems research. To support their relevance, the building features two systems that were developed by the faculty. The first is an innovative new structural system called a zipper truss. It had emerged out of necessity, as it is located above a central common area, while also supporting an irregularly shaped green roof. While several other strategies were explored, the wood and steel zipper truss proved to be the most effective system. The principal architect of LWA, Tom Chung explains that it was an ideal “combination of a dynamic form, architectural consistency, structural efficiency, and cost. It reinforces the overall building column grid, [which] allows for various span lengths while keeping the same form, and highlights the cost effectiveness of the digital fabrication process”. The system cleverly utilizes compression through 9” diameter glulam struts, which then translates into the steel tension rods from a central node. The whole system then connects to 18” glulam beams, which spans the common area. In addition to the zipper trusses, a second innovative system was introduced in the building. The floors were designed with a ‘wood-concrete composite floor’ assembly, which was also developed at the university. The intent was to eliminate steel from a poured concrete slab. This was achieved by replacing typical metal deck with a 5 layer CLT bottom layer, then fastening the two with a steel mesh. These two systems are strong examples of the type of innovative research conducted at the university.

Figure 19: (below): Facilities, classrooms and work areas surround the open spaces to create a sheltered courtyard and common area for the students.
Figure 20: (above)
The rooftop courtyard is an informal space for students to gather, while providing a unique canvas for the landscape architecture students to experiment with.
Figure 21: The copper coloured aluminum panels were designed to be reminiscent of the forests that surround the site.

Figure 22: Architectural model of the design building
Endnotes:


4. Schuler 2018


6. Schuler 2018


Figure 23: Interior of the Embodied Computation Lab
3.2 Embodied Computation Lab

Location: Princeton, New Jersey
Architect: The Living
Size: 8,500 sq. ft.
Complete in: 2017

Introduction
The Embodied Computation Lab was built to provide an interdisciplinary research facility in robotics and sensors for the School of Architecture at Princeton University. The building was designed to not only offer the tools to experiment, but it itself acts as an experiment.

Project Description
Architect David Benjamin, describes the Embodied Computations Lab as "simple in form but sophisticated in function. It involves an “open source building” to host research on the future of construction and computation. Just as biologists use an electron microscope to study organisms, architects will use this structure to study buildings.”¹ This notion was further expressed while speaking with Grey Wartinger, (the manager of the lab) he explained that the facility was “designed for open accessibility and adaptability. Its very construction is something that can be disassembled and move to another site. The building is consequently used in that manner, with temporary structures being grafted onto the framework and machines and tools are floating around the shop.”² This notion of adaptability is further supported by the fact that “A third of its framework, for instance, extends out beyond the enclosed structure, providing researchers with the bones to build out their own wall assemblies.”³

The 8500 square foot facility is modestly sized, which hides the fact that it produces innovative and high tech research in architectural building technology. David Benjamin explains that “Part of the challenge was figuring out the type of equipment that will be needed for research not just next year but also in five, 10, and 20 years”.⁴ So it was important to consider the evolution of technologies and designing a space that will provide enough flexibility to accommodate that. The resulting building takes a long and narrow rectangular form, spanning 140 feet
by 52 feet. The width of the floor and the 23 foot ceiling height was partially determined by the space required by the robots that would be installed. The building is subdivided into six areas. Located at the south west side is the main and largest space, reserved for robotics and automation research. To the east is an exterior testing area as well as a space for environmental systems testing (located inside of the existing labatut pavilion, designed in 1950 by then professor Jean Labatut). At the northern side of the building, are the restrooms and workshop, with a mezzanine overhead which acts as an instructional space for the students.5

The structure of the building is formed by large parallel strand lumber columns and beams. It is the first all timber system in the United States to support a five-ton gantry crane.6 This serves as proof that sustainable wood systems can in fact be used for structurally demanding situations. Beyond the research and testing of the materials, the building utilises other innovative environmentally conscious solutions. For example, the radiant floor “is heated through waste water from the nearby chemistry lab”.7 It also doesn’t waste energy with air conditioning, as the large hydraulic doors provide passive cooling. Since the building is adaptable, it can be adjusted to better suit its environmental condition by simply upgrading or changing its components.8

Figure 24: Image of the extended framework, or “bones” for future wall assemblies
Figure 25:
Exterior Photo of the Embodied Computation Lab
The Embodied Computation Lab’s relationship to site holds historical significance for the school of architecture. Since the 1940’s, it has been the location of innovative architectural research. Before the construction of the lab, work was conducted inside of a small horse stable. Additionally, the location “hosted Buckminster Fuller’s first Geosphere, the pioneering environmental analysis of Victor and Aladar Olgyay, and the architectural camouflage studies of Jean Labatut (glass pavilion)”.

In the context of the Princeton University campus, it is located at about a 10 minute walk to the south east of the School of Architecture.

**Facilities & Tools**

To suit the needs of approximately 20 students and half a dozen faculty and staff, the computation lab features:

- 7 robotic arms (of different sizes)
- A small metal shop, which supports:
  - 3-axis milling
  - Welding
  - Metal cutting
- A small woodshop with various tools
- A small metal foundry for metal casting

*Figure 26: During use, work stations and equipment are moved around in order to work within proximity to a project. Photo taken during a visit of the facility in February of 2019*
Research

The Embodied Computation Lab building is an architectural experiment in progress. Within the building's walls, are sensors for tracking and analyzing the thermal performance of the experimental cladding system. Researchers are examining the thermal properties of wood. More specifically, they are looking at how air gets trapped within the wood grain, and how perhaps the grain geometry can affect thermal characteristics. David Benjamin (founder and principal of The Living) explains “Normally, equations for heat transfer assume a fixed coefficient for surface roughness. […] But maybe that doesn’t have to be just a fixed coefficient. It’s one of those rules of thumb that’s passed down for so long, but nobody says: ‘What if it could be different?’”

To conduct the experiment 380 reclaimed boards from New York City Scaffolding were chosen, analysed and prepared. It needed to be. The research team needed to devise a technique for emphasizing the wood grain. They decided on CNC guided sandblasting, but needed to map out the knots in order to avoid them. To do so efficiently, a machine learning algorithm was developed, which was capable of locating the unique knots in each board. Once prepared, the boards were installed into the façade of the building and are being constantly evaluated.

The Embodied Computation Lab allows faculty and students explore architectural research in new and interesting ways. It highlights the potential of natural systems and materials, while utilising cutting edge digital technologies.

Figure 27: Close-up image of the exposed grain, sandblasted out of reclaimed boards from New York City Scaffolding
Figure 28: Main floor plan of the Embodied Computation Lab
Figure 29: Exterior photo of the lab, including the Labatut Pavilion
Endnotes:


2  Wartinger, Grey. Interview by Marc Bartolucci. e-mail. October 31, 2018


4  Ibid.

5  Ibid.


7  Wartinger. 2018


9  Klimoski. 2017


11 Wartinger. 2018

12 Gerfen. 2018
3.3 Hooke Park

Location: Dorset, Southwest England
Architect: Architecture Association School of Architecture students
New construction: 1987 - present

Introduction

The Architecture Association’s Design + Make graduate program is located within Hooke Park, a 150 hectare forest. The notion behind the woodland campus is to cultivate a stronger understanding of landscape, fabrication and design-build principals. “Underlying these activities is the opportunity to develop new rural architectures and an ethic of material self-sufficiency.”¹ Hooke Park hosts approximately 12 full time students, another 16 visiting students and 8 staff members.² The campus was originally established in 1987 by the Parnham Trust’s School for Woodland Industries (previous owners). In 2002, the Architectural Association School of Architecture (AA) acquired the campus including three unique buildings, the Prototype house (1987), The Workshop (1989) and the Dormitory (1996), which were constructed by the School for Woodland Industries.³

Figure 30: Aerial photograph of Hooke Park
The masterplan for the campus is focused around the values of the school’s teachings, including new facilities which are designed and constructed by its students. Currently the first construction phase of Wakeford Hall is in progress. The building will provide a library, lecture hall and reception area for the school. Hooke Park is a branch of the AA, which was originally founded in 1847. Mainly based in Bedford Square, London, the AA is the oldest architecture school in the UK. In total, it hosts approximately 750 students.4

Project Description

Hooke Park is comprised of an ecosystem of buildings that form the campus. There is a refectory, as well as living, work and storage spaces for students to use. Each building was designed and constructed by students and faculty. There are three buildings reserved for design-build research and fabrication. Each performs a role in a different part of the ‘making processes’. First, the wood must be gathered from the forest and cut, next, it must be fabricated and third, it must be assembled. Each of these areas suits the needs for the steps in that process.5

The Sawmill:

The first step of the construction process is the production of the building materials. At Hooke Park, the materials for projects are sourced from the surrounding forest. In order to utilise all of this local timber, a small WoodMizer saw is used to mill the trees into timber.6 During the 2016 – 2017 school year, a new shelter for the Sawmill was designed and constructed; faculty and students explored the potential of timber in tension for this project. They designed a “lightweight anticlastic timber net which spans nearly 11 meters while made up of timber laths of just 38x38mm in section.” This structure was clad in CNC cut 6 mm plywood and finished with thin aluminum sheets. The resulting shelter is a unique curving form that explores the potential of wood systems in tension. This design is reminiscent of the work of architect-structural engineer Frei Otto, who became famous for his investigations of tensile structures. The shelter serves to not only meet its practical needs, but to explore the potential of old knowledge in a modern context.8

The workshop:

The workshop building provides the space and tools necessary to work timber into a desired size and form. Designed by Richard Burton and Frei Otto in 1989, the workshop is a three tiered turtle shell like
Figure 31: The sawmill shelter
Figure 32: The Fabrication Workshop
bays, designed to study wood compression arches over long spans. The structure consists of long spruce thinning’s of approximately 100 to 150 mm in diameter, which are fixed at their base, and bent inwards to tie into a central component. This construction methodology is not dissimilar to that of an Iroquois Longhouse. This structure is covered with two layers of PVC insulated membrane, forming a shell like surface condition. Ventilation occurs in the summer through low level window panels which run along the building edge. During the winter, the concrete floor is heated, effectively warming the space evenly. Two of the three bays are used for the workshop, while the third and western most bay contains studio and office spaces. The workshops construction is experimental and reflective of the type of advanced design-build research conducted at the Hooke Park for the past three decades.

The Big Shed:

The Big Shed building is used for project assembly. This occurs in a multi-faceted wooden building that features irregular geometries to create a large, open building with a 9 meter x 6 meter door. Similar to the other buildings, this build space is the embodiment of research and material exploration. The structure is built with a framework of trusses made from un milled trees to create its unusual form. Each of these trusses are unique, due to the nature of the logs and their individual shapes required to meet the design of the building. This required an analysis of each tree to calculate its connections and position in relation to its neighbouring components. Once calculated, these members were then joined with long timber framing screws in order to provide maximum

**Figure 33:** Kuka robotic arm, with a chainsaw attached for the milling of a log
Figure 34: Interior of the Big Shed
Figure 35: Exterior of the Big Shed
strength. The cladding for the structure is made with western red cedar boards, which were harvested from the local forest. On the roof, natural light can penetrate to the core of the building through triangular skylights. The Big Shed serves to inspire the potential of unconventional design thinking when combined with sustainable forestry practices.

Facilities & Tools

Hooke Park features 3 making facilities, each specialising in the different aspects of fabrication.

Fabrication Workshop:
Equipped with the tools necessary for wood working, this main shop is used by a maximum of 16 students, over 12 workbenches.

• Workshop machinery
• 3-axis CNC
• A variety of saws
• Planers
• Drill press
• Sanders
• Boring machine

Figure 36: Within the Big Shed, Students piece together the truss system that will form the Big Shed project from 2012
• Portable Tools
• Battery operated saws
• Drills
• Grinder
• Router
• Drivers
• Nail gun

Assembly Workshop:
The assembly workshop provides 400 square feet of covered space, designed for larger design-build construction projects. The space can also be rented out to visiting groups when it is not in use. The space includes:
• Portable dust extraction
• A pneumatic compressor
• 3 phase power
• Stena re-saw
• Kuka robotic arm (Kuka KR-150, 2000 series)
• Equipped with spindle, gripper, chainsaw and band saw end effectors
• Scaffolding

Sawmill:
The 'WoodMizer' sawmill is a small mill capable of cutting locally sourced tree trunks into timber for student projects.

Research
The ‘main project’ is central to the Hooke Park’s architectural research agenda. Students utilise the forest surrounding the school as a site to conduct research through making. The curriculum is entirely based around this premise. Following an introductory studio and a seminar course, the rest of the school year focuses on a ‘main project’, which could include a build phase and/or an individual thesis. For the M.Arch students, the ‘main project’ will be a permanent building on the campus. Student groups will design, fabricate and assemble their full sized structure on site. This methodology allows students to generate research, and then test their hypotheses through the realisation of architecture in their thesis. New projects are constructed every year; the following are a few examples.
Figure 37: As a part of her dissertation: *Slow Joinery*, Laura Welsh built a bench that cannot be sat on until the connection between the cast aluminum and the sappling grows and strengthens over time.

Figure 38: *Cocoon* is a weaving cedar strip structure, suspended between trees in Hooke Park
**Slow Joinery:** This project is a series of long term prototypes. The idea is to join inorganic objects such as aluminum, with the organic, through the slow process of growth. The dissertation entitled *Slow Joinery: Design with Adaptive Growth*, by Laura Welsh. The project is based around the process of growth, observing how trees grow around and through obstacles over time. Welsh’s desire was to use this process to create objects, which will not be functional for at least the next 10 years. She made a cast aluminum bench, with one end connected to a stump, while the other is a loop, positioned around a sapling. The seat cannot be sat on until the tree has grown large enough to support the weight.\(^{15}\)

*Cocoon* is a material study experiment, in the attempt to make a stiff structure out of thin cedar strips. The structure is built by weaving or ‘bandaging’ cedar strips within each other. The resulting form resembles the shape of a cocoon or weaver bird nest. Once stiff enough, the structure is hung between trees. Finally the students built a skeleton out of plywood cut out on a CNC to give it more permanence. The Cocoon is oriented towards the sunset. As a result, this form gives a unique visual and tactile experience to visitors who come to hide in the environment.\(^{16}\)

The Architecture Association provides its students with a unique learning environment at Hooke Park that immerses them in a wood fabrication workshop in the forest. The Design + Make program explores learning through making full scale built structures that are integrated within the ecosystem at the park. Additionally, the focus on wood and the school’s connection to the local forest reinforces the idea sustainable design thinking and building practice. The graduate program at Hooke Park merges traditional material craft with cutting edge innovations and technologies.
Endnotes:


2 Joseph Mollica, Zachary. Interview by Marc Bartolucci. e-mail. November 6th, 2018

3 Ibid.

4 Ibid.


6 Ibid.


3.4 **Structure Craft Facility**

Location: Abbotsford, BC  
Architect: Keystone Architect  
Size: 50 000 sq. ft.  
Complete in: 2017  

*Introduction*

StructureCraft is a sister company to the structural engineering firm Fast + Epp, it was established in 1998 by Gerald Epp. It was founded as a mass timber design-build company, capable of building the unique designs from the engineering firm. Its process is to design and prefabricate the components for a project, with the ability to then ship and install its product on site. StructureCraft aims to highlight structural expression through quality craftsmanship of challenging projects. Since opening, the company has built a reputation for its work in timber construction by working on projects such as the Calgary Central Library, the Surrey Memorial Hospital and the Bow River Pedestrian Bridge in Banff. Over the years, the business has experienced continuous growth, in order to meet the needs of their clients and to maintain efficiency; a new, larger and more specialised facility was constructed in Abbotsford, BC.

*Project Description*

Since StructureCraft designs, fabricates and installs prefabricated mass timber components, its new facility was designed to showcase their capabilities and their products. With this construction methodology in mind, they were able to assemble all of the prefab components of the building in only 5 days. The entire building was designed with practicality in mind, which resulted in large open spaces for manufacturing, doors large enough for trucks to drive in and skylights arrayed throughout the roof to allow natural light to reach the centre of the workshop. Some of the materials used in the construction include DLT, CLT, Laminated Strand Lumber, Nail Laminated Timber, glulam beams and prefabricated systems.
Figure 39: StructureCraft Facility
In order to assemble the facility in such a short timeframe, many prefabricated units needed to be designed and fabricated ahead of time to permit continuous construction. The first building elements to be installed were ‘tall wall’ panels, tied into the poured concrete foundation. These consisted of large 12 foot wide by 30 foot tall wall systems. Essentially these were pre built walls, with insulation, moisture barriers and sheathing included. Following the wall installation, the 12 foot by 63 foot long roof panels were transported to the site and lifted into place. The roof panels rest on a central longitudinal glulam beam. The roof was “preconstructed on site with glulam-edge beams-bridged laterally by conventional solid-sawn joists; while wall panels have Laminated Strand Lumber (LSL) studs”. The central glulam beam divides the workshop into two separate bays. One is used for fabrication projects, while the other side is dedicated to DLT manufacturing. According to StructureCraft the “building [is] comprised of 233,924 board feet of wood products, [and is] equivalent to about taking 250 cars off the road for a year or enough energy to operate 125 homes for a year.”

**Facilities & Tools**

The facility at StructureCraft includes two buildings. The first is the Warehouse/Workshop; the other is the L-shaped office building, connected to one of the corners of the shop. It accommodates approximately 40 employees in the office and another 40 craftspeople and machine operators. The facilities tools include:

- Basic carpentry tools
- Large CNC’s
- Manufacturing machines for producing products such as DLT.
- 4 gantry cranes

**Research**

The primary focus of the company is to produce custom built structures and systems, as well as the installation of these components on site. In order to rethink the notion of mass timber and prefabrication, StructureCraft conducts research and development. Recently, they produced a new product called Dowel Laminated Timber (DLT). DLT is an innovative timber paneling system that replaces nails and glue for dowels, creating a component made entirely out of wood. The building product is the first of its kind in North America and it has captured the attention of architects and designers for being both sustainable and economical. Another wood building product created by StructureCraft is the Wood
Figure 40: Samples of Dowel Laminated Timber Panels

Figure 41: A single, assembled Wood Wave panel
Wave Panel. These panels are formed by long and hollow V-shaped beams, built out of standard dimensional lumber. This system innovates the use of typical lumber, as it produces long spanning curving panels.\textsuperscript{10} In addition to its products, StructureCraft has also developed other innovative timber systems to meet the needs of specific projects. On the Philip J. Currie Dinosaur Museum project for instance, a unique layered plywood node was developed in order to connect up to 8 angled glulam beams and struts.\textsuperscript{11} Working in collaboration with numerous architects, the engineers and craftspeople at StructureCraft have developed many new wood structural systems and building assemblies' and are considered a world leader in advanced wood building construction.

StructureCraft plays an important industry role in the research, development and promotion of sustainable wood construction methodologies. Their focus on timber fabrication is not only exemplified through their work, but it is also demonstrated in their facility. They produce elegant and innovative ideas that translate strongly into the built environment. Their work represents the role that structural design, fabrication and other environmentally conscious businesses can achieve in the built environment. Furthermore, their work demonstrates the potential of prefabrication as a methodology for a higher level of tectonic articulation in construction.

\textbf{Figure 42:} (below) The Richmond Olympic Oval features Wood Wave panels, incorporated within the roof structure.
Figure 43: DLT Panel being installed into the ceiling of the office space in the StructureCraft Facility
Figure 44: The StructureCraft facility in Construction
Figure 45: Facility interior
Endnotes:


6. Ibid.


8. Epp, Gerald. Interview by Marc Bartolucci. e-mail. October 29th, 2018


3.5 Kauffmann Zimmerei Und Tischlerei

Location: Bregenzerwald, Austria
Architect: Johannes Kaufmann Architekture
Size: 3 600 sq. m
Completed in: 2017

Introduction

Kauffmann Zimmerei Und Tischlerei (KZT) is a 4th Generation Construction and Carpentry business in Austria. They specialise in wood assemblies that combine traditional wood working practices with modern technologies. As a result, the company specialises in prefabricating high quality wood building components for homes and small commercial buildings. Out of necessity for space, they built a new assembly hall (neue montagehalle).

This new facility showcases the capabilities of the builders, environmentally conscious design, as well as the potential of wood when combined with high levels of craftsmanship.

Project Description

Kauffmann Zimmerei und Tischlerei's business model is founded on the creation of prefabricated wood products, for the building industry. The notion behind this approach is to utilise the benefits of prefabrication, craftsmanship and of wood, for a higher level of quality and speed during construction. The prefabrication component to these modules is key.

By bringing the construction site indoors, builders are able to control their working environment. Sheltered from weather, it is possible to work in ideal conditions. Additionally, since these modules are being built within the facility, access to tools and resources are not an issue. It eliminates the worry for the availability of electricity, water or compressed air. Furthermore prefabrication is an opportunity for sustainable workmanship. In a normal on site construction model, it is not uncommon for waste from wrapping paper, off cuts or undesirable material to collect. Through thoughtful design and fabrication, these issues can be virtually illuminated. These modules could be designed to use specific amounts of material, which could be custom made for a project. Or if there is excess material, it is much simpler to collect and recycle it when it is inside an enclosed facility, rather than outside. And since these modules are sent away pre-assembled, wasteful wrapping papers or plastics are totally unnecessary.
Figure 46:
Kauffmann Zimmerei Und Tischlerei’s new Assembly Hall
Figure 47: Assembly Hall interior
KZT’s focus on wood makes their prefabricated product very relevant to modern issues within the building industry. With the growing need for environmentally conscious design and construction, prefab wood products along with innovative new engineered wood technologies, generates an interesting new perspective on the future of the built environment. Products such as CLT, glulam, DLT and parallel strand lumber (to name a few), are changing the ways in which we think about building, and are ideally suited for prefabrication. It can be used in just about every aspect of a building, from structural components, to sheathing, to finishes. It is also commonly available in many parts of the world, and is easy to work with. All of this is therefore making it an exciting material for precisely this type of work.

The prefabrication methodology also offers the potential for a higher level of craftsmanship. On site, tools are mostly mobile out of necessity, since they need to remain in proximity of the construction work. This unfortunately limits access to tools and proper conditions, which in turn lowers the quality of the workmanship. While in a facility such as the Assembly Hall, workers have access to more tools and better conditions for working. In fact, buildings such as this one or StructureCraft are specifically designed for this type of work, and therefore provide the most ideal situation possible. Spaces such as these are much more than just shells or shelters, but they actually act as incubators for exceptional craft and sustainability.

Facilities & Tools

The large single storey mixed-use facility is designed for large prefabrication projects, which results in large, high ceiling, floor spaces for work. Some of the tools and elements to the facility include:

- Basic carpentry tools
- Powered wood working tools (saws, drills, sanders, etc.)
- Two 20 tonne gantry cranes
- Two 5 tonne gantry cranes
- Rolling carriages, built on floor tracks for manipulating room modules
- 4 forklifts
- Hand pallet trucks
- Multiple docking points (electricity and compressed points)
Figure 48: Exterior of the Assembly Hall

Figure 49: The attention to detail and craftsmanship is visible during the construction of the Assembly Hall. The image illustrates the joinery in the mass timber structure.
Research

Over the past 20 years, KZT has been developing prefabricated wood modules, which they call ‘Holzmodulbau’ in German. This is a modular system that can be easily customized for individual projects. With careful planning these modules can be built to a finished product, called ‘turnkey completion’. This would include elements such as wiring, HVAC, plumbing and interior finishing, which will then only require onsite placement. Since these are designed to be easily shipped on flatbed trucks, this system creates the opportunity for multi-unit assembly. Not unlike a Lego building block, they can literally stack on top of each other to create a larger building assembly. With this highly refined methodology for construction, multi-storey wooden buildings such as offices, hotels, nursing homes or residences have successfully been built up to 6 stories in height. Although this approach to construction is not necessarily new, KZT harnesses their skills and experience to raise the potential of offsite construction in their own, unique style.6

A unique example of these wooden modules can be found in Dubendorf, Switzerland. Built for the Swiss Materials Testing and Research Institute (EMPA), KZT fabricated and assembled several 8 ton modules for the project.7 A key challenge to this project was the requirement that all materials used would either be recyclable or compostable. So as a result, each of these is built with a spruce post and beam structure, along with wooden finishes for the interior. On the exterior, these modules feature aluminum and copper cladding. This project is unique for its assembly. Since this was built for a research institute, the walls feature innovative insulation systems made from three vastly different materials. The first is panels made from mushroom mycelium, next is a recycled stone, and then in other parts, is insulation made from recycled resources such as old carpets.8 Rather than simply stacking these modules on top of each other, a unique cantilevered structure was designed, which gives the buildings elevations, an unmistakable look. It almost appears to be somehow off balance.9 Perhaps it is a comment towards the shifting tides, with timber re-emerging as a dominant material.

Kaufmann Zimmerei und Tischlerei is an important precedent for the design of a wood architecture research and design centre. Their speciality in wood construction is proof that the material can play a larger role in the built environment. Furthermore, their work illustrates that timber can also participate in the more industrial fabrication processes,
without ever losing the sense of quality. Through thoughtful design and craftsmanship, the potential aspects relating to sustainability are also very strong in this type work. Material waste could potentially become obsolete. Lastly, a prefab construction methodology similar to that of KZT, is a practice that shows a lot of promise for the future of timber fabrication in the building industries. Products such as these modules can drastically reduce on site waste and construction time. For me, I see this as the foundation, for an industry that is heading towards its next evolution.

Figure 50: Fabrication of the modules for the EMPA
**Figure 51:**
Installation of one of the wooden modules onto a larger assembly of modules to create a full building

**Figure 52:**
Installation of modules
Figure 53: Completed unit assembly
Figure 54: A wood module is being loaded onto a flat bed truck with the help of the gantry cranes inside of the hall.
Endnotes:


2 Ibid.

3 Ibid.


3.6 Autodesk BUILD Space

Location: Boston, Massachusetts
Architect: Spagnolo Gisness Architecture (SGA)
Size: 34 000 sq. ft.
Completed in: 2016

Introduction

The Autodesk BUILD Space (ABS) is a large 34 000 square foot facility, which provides the room as well as access to numerous tools for researchers, makers, developers and small businesses. It serves as a research and development space for studying new tools and materials such as robotics, 3D printing, wood, composites, textiles and more. It generates a symbiotic relationship between its 500 plus residents and Autodesk. On the one side, cutting edge research is made possible thanks to the resources that are made available. While on the other side, Autodesk makes the trade with new contacts and a glimpse to the future, informing the direction for their software development in the upcoming years. The idea behind the build space is to empower hard working individuals with the resources they need to innovate the environment that surrounds them.
Figure 56: Open floor connection between the ground floor and the second level. A gantry crane uses this opening for transporting heavy objects between floors.
Project Description

The Autodesk BUILD Space is a large facility, located in the southern end of Boston, not far from the main channel. Along with its goal to assist designers, makers and researchers, even the place it occupies, demonstrates its values. It is an example of adaptive reuse. Along with other businesses, it reinhabits an old concrete building, which was once a part of a military base. In order to meet the needs of the new residents, builders were required to make cuts in the floors and walls; in order to provide the room required. Furthermore, a later development to the BUILD Space is the need to add an additional floor. This has become an additional exposition of what this facility is all about. In order to maintain structural stability after making large cuts for a third floor, the architects are utilising carbon fiber support members for the openings. In a sense, the space was designed to reflect that ideas and the work that is being generated there.

The design of the BUILD Space was programmed around two primary requirements. The first, of course, is simply providing the room required for all of the equipment that Autodesk is providing to its members. Due to the sheer amount of tools and machines available, they reside on both floors out of necessity. The second requirement is workspace. Once objects, prototypes or products have been fabricated, assembly or further post processing may be necessary. Work tables and open floor space can be found scattered throughout the building, making it more evenly accessible, no matter where someone may be working. Additionally on the second floor, an open concept work space is accessible to residents. It provides computers with access to Autodesk softwares, desks and meeting spaces. All in all, the notion behind the program is to provide as many of the resources as possible, to allow people to follow their projects through, from start to end.
Facilities & Tools

Designed for versatility, The Autodesk BUILD Space supports the many tools necessary for working on a variety of materials, fabrication processes and scales. Divided by floor, the ABS features:

Main floor:
- Several ABB Robotics arms of varying sizes (bench, floor and pallet mountings)
- Howick FRAMA steel framing forming machine
- Tube bending machine
- Ceramic kiln (2’x4’x4’)
- Glass fusing/slumping kiln (54”x42”x18”)
- Bel-o-Vac Vacuum Former (2’x4’)
- Freezers
- Wood shop tools (Sanders, drills, saws, hand tools, etc.)
- LAP ceiling mounted projector
- Composite curing oven (15’x10’x10’)
- Environmental Test Chamber (24”x24”x24”)
- 5 axis CNC router (60”x120”x41”)
- Welding and metal fabrication tools (welders, cutters and saws)
- 5 axis water jet (120”x72”x7”)

Second floor:
- JUKI industrial sewing machine
- Microelectronics tools (multimeters, soldering stations, oscilloscopes, etc.)
- Vertical Manual/CNC Knee Mill
- Variety of drill presses
- 3 axis machining centres
- Haas ST-20Y CNC Lathe with Y axis
- Leblonde Makino Engine Lathe (19”x54”)
- Wood shop (saws, sanders, drills, lathe, dust collectors and a CNC Router)
- Dozens of 3d printers for any 3D printable material (PLA, ABS, Nylon, Fiberglass, Kevlar, Carbon Fiber, etc.)
- 4 Epilog Fusion40 laser cutters (40”x28”x13.2”)
- Roland Sp-300i VersaCAMM Vinyl Printer/Cutter
- 5-ton bridge crane
- Work spaces
- Computer Lab
Research

Located in Boston, students from MIT and the Harvard Graduate School of Design (HGSD) utilise the space to explore newly emerging building technologies and techniques, in the search to develop new conceptual theories, which could one day inform the future of the built environment. One such project is *Heliomorphic Chicago*, by the HGSD. The term Heliomorphism was coined by Vladimir Matus in his 1988 book, *Design for Northern Climates*, within which he argues for an urban planning that considers its relationship with the sun. Matus became known for his work with heliodons, a device which would simulate the position of the sun, and shine artificial light onto model buildings. He would use this device to inform an architectural response to the constantly changing position of the sun. The concept of Heliomorphism then emerged, with a built environment that was studied with a heliodon, and then designed or transformed (morphed) as a response.  

Figure 57:
Researchers explore human-robot interactions
Figure 58: Models of a heliomorphic Chicago. These demonstrate the reimagined building of the city, influenced by the sun’s rays.

Figure 59: Rendering of the proposed 3D-printed Martian habitat, by the start up company AI Space Factoy.
In 2017, Professor Charles Waldheim along with graduate students from the HGSD, sought to explore the concept of an alternative Chicago. The idea was a "radical reimagining of Chicago’s urban form through optimized solar performance." The project presents the city’s iconic buildings through this heliomorphic lens, with two alternative approaches. The first is a social equity, where the buildings have been carved and modified, to allow as much access to sunlight as possible to its surroundings. Then the second is the same morphing of architecture, but for the maximization of solar energy absorption. This theoretical investigation drastically transforms the Chicago skyline, for one that seems to have been cut and shaped by the rays of the sun. This project was made possible through its relationship to the BUILD space. Students had access to the tools they needed in order to model, prototype and build this alternative Chicago.

On top of supporting academic research, the ABS provides access to numerous resources the greater community around it. Businesses, industries and individuals are also given residency. AI Space Factory (AISF) for one is a start-up company that is competing to research and

**Figure 60:** View from below the second floor opening and gantry crane
develop a construction process for building on Mars, through NASA's 3D-Printed Habitat Challenge. The idea of humans walking on another planet is simply a question of time. Companies such as SpaceX, Boeing, Blue Origin and of course NASA are pushing towards Mars. Although traveling the immense distance is the first problem to solve. A second fundamental problem, is building the Martian infrastructure once they get there. AISF is attempting to create a system that will overcome this barrier.

AISF’s project is called MARSHA; an additive manufacturing system which they are developing at the Autodesk BUILD Space. Their research is founded on large scale 3D printing of tall, cylindrical structures, from resources found and made on Mars. The material they intend to use is a “basalt fiber-reinforced polyactic acid”. This is a formulation of basalt fibers found in Martian rocks, and bioplastics, made from plants growing on Mars. AISF is undergoing tests with the help of robotic arms to develop and refine their cutting edge technologies. The tools necessary for this type of work is normally inaccessible. It is thanks to the BUILD Space, that even small companies are capable of generating innovative new research, which could one day inform, an interplanetary future.

Autodesk has created the ultimate maker space. It is founded on the idea of empowering students, small businesses, researchers or any other individual that may need access to the resources they provide. Through a plethora of tools and machines, innovative research such as Heliomorphism; and the development of Martian infrastructure is made possible. As a result, they manage to stay connected with the creative people that are helping to shape the future. Not only does this allow them to be involved, but it also provides them with this unique opportunity to see how their products are being used, and how they can further empower their users in the future. It is a symbiotic relationship that generates innovation.
Figure 61: Exterior of the Autodesk BUILD Space, built inside of an old military structure near the main channel in Boston
Figure 62: Image of some of the robotic arms available at the BUILD Space
Endnotes:


3 Lubell, 2018

4 Ibid.

5 Ibid.


Chapter 4: Architectural Wood Assemblies Design & Fabrication

Drawing upon the wood building products research and wood research facilities case studies outlined in the previous chapter, a series of wood assembly experiments have been explored, in order to move towards the development of new building systems. Throughout the design research and fabrication process, a series of models that investigate different concepts approaches and methodologies were created. Similar to the case study facilities, this design research examines wood in order to discover new fabrication possibilities. Working at a 1:50 scale, the research explores a variety of building systems such as wall or roof assemblies. As well, abstract sculptural prototypes experimenting with weaving glue laminated structures were made. This exercise serves to imagine the potential and the possibilities for the design of the Wood Research Centre at Laurentian University.

The following outlines a selection of the wood assembly prototypes produced:

1. Alternating Roof Assembly

   This model was based on the notion of a staggered truss which is reversed at intervals. I was interested in the geometry required to connect each of these triangular trusses to each other. The generated form creates something that is not dissimilar to a simulated curve. At first glance, this assembly seems relatively versatile. It could simply be placed horizontally on a roof, but on the other hand, it could form a wall if stood vertically on its end.

2. Repetitive Saw Tooth & Sloping Roof Assembly

   Similar to the Alternating Roof Structure, these structures were created so that they could be oriented in multiple directions. If used as a roof, it could be placed horizontally. Positioned as a wall, it could be either horizontal or vertical. The saw tooth shape generates an opportunity for glazed openings, which could allow natural light to penetrate.

Figure 63: Image of prototype roof assemblies
3. Recycled Materials Partition

Standard lumber is a very versatile material. Designed for the facilitation of building assemblies such as walls, roofs or floors, it has become an integral aspect of construction in northern Ontario. As a result, it is also not uncommon to find it being used for other things as well, furniture, toys, tools or jigs are all part of the multifaceted nature of the material. Unfortunately, one of the most common problems with standardized lumber, which all of these uses share, is its inherent wastefulness. Since projects require specific lengths of wood, there will always be off cut material, which will often collect in a pile to be eventually discarded. The recycled materials partition is inspired by this concept. The model explores the possibility of reusing these off cuts, and making something new and interesting.

4. Insulated Wall Assembly

This model wall assembly is a play on the concept of layered Cross Laminated Timber. Since CLT is generally available in layers of 3, 5 and 7. I thought that it could offer an interesting opportunity for a multi material integration. Perhaps it would be possible to sandwich rigid insulation between the laminate wood layers. If a system like this could work, perhaps it would offer the opportunity for a totally new type of wall assembly, which would be entirely prefabricated, and would only require installation. With this sandwiched wall theme in mind, I created three separate models. The first is a basic wall with a window opening. The second is a prefabricated wall, with a milled edge to create pattern. The third is another iteration of a milled wall, but with subtle curves introduced, which might be used in a space, to reflect its dynamic occupants.

5. Curving Glue Laminated Beam Study

Digital fabrication offers new possibilities within the building industry. One of which, is the combination of advanced tools, with traditional material understanding, to create something new. With an interest in structural systems, this exploration, seeks to combine these aspects.
Wood engineering technologies have revolutionized the construction industry. It has no longer become uncommon to see mass timber, as a main structural component in buildings. This is signaling that there are new opportunities for designers to replace steel and/or concrete, with the much more sustainable material. The McEwen School of Architecture for instance, features long spanning glulam beams resting on large CLT walls. The issue however is that, as the alternative name suggests, they are mass timber constructions. In most cases large wood buildings feature huge timber modules that are purely functional and overly engineered. There is usually not a balance between form and function, leaning more heavily towards the former rather than the latter. With the introduction of modern tools and technologies, digital fabrication has permitted an alternative approach to beam design.

This research is inspired by two case studies the Xie Xie Café, in Hangzhou, China, and the Maggie Centre, in Manchester, England.

The Xie Xie Cafe in Hangzhou, China, designed by Koo Architect took a unique approach to incorporating beams into the existing café. The space is divided in two, with the one half featuring a large sun room like space. Originally built from a steel and glass construction, the materials evoked an atmosphere that felt cold and artificial, while also over exposing the customers in sunlight on brighter days. As a result, the architects designed a system of weaving wooden box beams that not only offer a structural support for the glass roof above, but filters the light for the patrons below. The warmth of the wood coupled with the unique shadows generated by the structure overhead created a more inviting and comfortable space for people to sit and enjoy themselves.¹

While the cafe is a smaller scale example of innovative thinking with wood component, The Maggie Centre in Manchester uses a unique beam design as its primary structural system throughout the building. Maggie Centres are created to act as a sort of refuge for cancer patients. They provide a safe place where people can find support while they heal. In these centres, architectural program plays a key role during these difficult times. Designed by Norman Foster, a cancer survivor himself, the idea for this building was to immerse the patients in a garden like atmosphere. Constructed within a well sunlit sight, the triangular roof features a series of skylights arranged in odd angles and in geometric patterns that are reminiscent to greenhouses. Gardens, natural light

Figure 65: Image of the interior of the Xie Xie Café demonstrates its weaving wood structure that filters the sunlight from the glass roof above.
and views to the surrounding nature are found all the way through the centre. To strengthen the idea behind the design even further, a visible wood structure emphasises the connection to nature. These are a series of long tapering laminated veneer lumber (LVL) trusses that act as the beams, joists and columns throughout the building. These were designed with a trellis-like web pattern, routed out of their centres. Not only do these beams provide a visual connection to the conceptual idea, but they likely make installation easier due to weight reduction and the process of prefabrication. Additionally, they do not block as much light as a solid mass would, making interesting opportunities for shadows at different times of the day. The structural system in this Maggie Centre is proof that they can be more than just functional.

Combined, these two projects are fascinating precedents that tie into my interests relating to double curving laminated wood. In order to help give myself something to start from, I thought that it would be important to ground my work within a certain scenario. So I positioned myself in a situation where I am working within a space like the Xie Xie Café. So I needed to develop a system that could not only perform its structural needs, but strengthen the design in the space, filter the natural light; and create unique system that features interesting connections. The idea is to attempt to create a system that is both structural and architectural.

After multiple iterations, a structure was modeled, which could filter light through a unique structural system, which weaves in and out of itself, similar to a wave. I thought that this could create an interesting opportunity to examine joinery and curving glue lamination. In order to build a model of this structure, the system was broken down into two components, a central node, and an arm. Each node connects to eight individual arms that curve out and back in to the next adjacent node (which can then continue on in the same pattern). After multiple iterations, dowels were chosen as the connection method between each limb, as other joinery methods proved to be ineffective at such odd angles.
Figure 68: The unique four part double curving beam creates an interesting opportunity to experiment with wood fabrication.

When the system is arrayed, it produces an interesting and unique assembly.
Figure 69:
The system is broken down into two separate components: Curving arms and central nodes. All connected through dowel joinery.
Figure 70: CNC cutting of MDF sheets to build a build for glue lamination of the beams

Figure 71: In order to prevent sliding, the mold for the arms needed to be cut to the same shape, then have guards installed in place to minimise movement.
Figure 72: (above)
The individual layers for the curving glulam beams are cut out of 3mm birch plywood on a CNC.

Figure 73: (right)
The layers are then stacked with a generous amount of glue in between. Pressed tightly in the mold and left to dry for 3 to 4 hours.
Figure 74: Before and after glue lamination of a prototype component

Figure 75: Assembly of prototype
Figure 76: The assembled prototype
To build these components, the 3d model was broken down into a two dimensional plane, generating a surface which could be milled out of 3mm birch plywood, on a CNC. This methodology creates the initial shape for the object, which will be then glue laminated into its final 3 dimensional (double curved) form, through the use of a mold.

Once assembled, the model created a fascinating form, which seemed alien in appearance. Although it is aesthetically interesting, it lacks the strength to support any other weight than its own. This is mostly due to the connection between the arms and the nodes. Pressure points are created on the joinery from the significant leveraging action from the long arms. The model proved to be an interesting first step in the exploration of curving glue laminated beams. Although this model is a failure, it is informing a second iteration for a beam.

6. Evolution of the Curving Glue laminated Beam

Although interesting in form, the first iteration of the double curving glue laminated beam suffered from some fundamental issues. The main, is the lack of strength in the joints. This is due to the fact that the arms, which connect to the node, reach out, unsupported, and then curve back in to make the connection. This is the flaw which creates weakness in the structural system. Therefore in order to utilise a double curved beam, support at the apex of the curve is necessary. For this second version, strength is found when pressing the two arms against each other, which creates an interesting opportunity for a structural system, that pushes glue lamination to new limits.

This structure has implications as well. If it were to be prefabricated, it could be built to fit transportation requirements, and then come to a job site with all of its necessary components installed. It would even include the roofing above it, with decking, insulation and a roofing membrane. Nearly complete already, it would only require installation, and to be joined with its neighbours to create a uniform, interesting structural system. The only issue that this X shaped structure introduce a void between each truss. This problem is solved by having a reversed, ‘eye’ shaped assembly, installed between two X shaped trusses. This way, a uniform and continuous structure can be quickly and easily installed on site. The goal behind this new assembly is to create a system that serves its structural purposes, while also creating uniquely interesting aesthetic. This is thus proving the argument that there can be a better balance between form, and function.
**Figure 77:** Assembly process for the second iteration of the double curving glue laminated beam. Layers are cut two dimensionally, glue laminated in a form, glued with a second beam to create the “X” or “Eye” shape, then framing is added last.

**Figure 78:** The shape of the truss requires an opposite form in order to fill the void it naturally creates. The system generates an interesting aesthetic and structural opportunity that could test the potential of prefabrication.
Endnotes:


Chapter 5: Laurentian University Wood Architecture Research and Fabrication Centre: Site Proposal

Since its inception in 2013, faculty and students at the McEwen School of Architecture at Laurentian University have been engaged in wood focused design-build research. The existing Workshop building where the research is conducted is currently at capacity and a new facility is required to support this ambitious research agenda.

The following architectural design offers a building proposal that applies the wood assembly design and fabrication research outlined in the previous chapter. The new Laurentian University Wood Architecture Research and Fabrication Centre will be located in Downtown Sudbury adjacent to the McEwen School of Architecture building. The 1500 m2 building will consist of a large open assembly triple height space and a second floor clean space to house digital equipment and research offices. The facility will include stationary manual wood tools as well as digital fabrication tools and robotics. This new facility will support the construction of 1:1 scale two storey buildings within a climate controlled environment.

Building Program

Advanced wood research is the driving force behind a building. It is important to understand faculty and student research interests, to identify the ways in which they would use the facility and develop the functional program. Therefore, I conducted a number of interviews to determine the tool and space requirements for the building.

The following programmatic requirements were determined from consultation with four professors, whose research interests are directly linked to the utilisation of a research facility, focused on fabrication and material development. The following description is broken down into these two categories, with a third to describe general aspects, in order to inform a building design.

Fabrication and Digital Fabrication

- Space for two tracked robotic arms (spaced approximately 2 meters apart, up to 9 meters long)
- Large CNC machines (approximately 6 meters x 3 meters in size)
• Large payload robot (arm radius of approximately 3.5 meters)
• A clean lab (safe from dust and excessive moisture, large enough for computer and other electronic work stations)
• Materials Research and Development:
  • Space for a shop with typical tools (table saw, band saw, sanders, etc.)
  • General wood storage
  • Climate controlled storage
  • Adequate space for large tools (wood presses, clamping racks, wood and steel bending machines, etc.)
  • Space for metal working (welding, cutting, forming, etc.)
  • Large open floor space to accommodate multiple large building projects (building full scale double curved beams, or prefabricating a small house), with a high ceiling.
  • Space for material testing equipment
  • Gantry crane for moving and supporting large projects

  
  **General requirements:**
  • Reception area
  • Changing room and personal storage space
  • Washrooms
  • Work tables
  • Approximately 4 or 5 offices
  • Meeting room
  • General storage (tools, material, food, etc.)
  • Loading dock/space

To accommodate the research requirements I have determined that a facility with a general footprint of at least 1500 m$^2$ (16000 ft.$^2$) is required.

**Building Site Analysis**

Within a 15 minute walking distance of the existing School of Architecture Workshop building, there are 4 empty properties that meet the needs of a wood research and fabrication facility. In order to examine their feasibility, I consulted the Director of Planning Services for the City of Greater Sudbury,¹ to understand the role that each of these sites are intended to play in the greater development of Sudbury, while also highlighting any particular issues that the site might have.
1. neighbouring the transit terminal

This parking lot provides an interesting urban opportunity for a research facility. By being located next to the city’s bus terminal, and only a block away from a main road, this site is likely to get a lot of exposure from the public. This creates an opportunity to not only promote the architecture school, but to also create an interesting urban dynamic, through architecture. Although interesting, the site just barely fits the bare minimum footprint, which means that there would be no space for large trucks, or for outdoor storage.

2. shoppers drug mart parking lot

This property was originally intended to be the location of the shopper’s drug mart store. However for better urban design, it was placed at the main street front instead. This site is ideal for connecting with the architecture school building, as it is only a minute’s walk away. The size of the lot is adequate for the building; however any major storage would have to depend on the main building itself. Additionally, the soil in this area is contaminated, therefore making it less than ideal before even starting construction.

3. corner of Douglas and Lorne

The property located at the corner of Douglas and Lorne is a large, open and relatively flat site, which is ideal in size for a research facility. It allows for plenty of room for the building, and for a large amount of space surrounding it, making outdoor storage possible. Additionally, the site is walkable within 15 minutes of the architecture school. At first glance, it seems like an ideal place; however it too, features some fundamental problems. First, the site is a contaminated from the neighbouring rail industry, which could require excavating a large amount of soil before construction. Furthermore it is difficult to access by car, due to its proximity to a busy intersection. And lastly, the property is privately owned, which could make it challenging to acquire. Although promising, this location is not ideal.
Figure 79: Site Selection Plan

Site Selection Plan
Scale: N/A

0m
50 100 150
4. Energy Court

The last site that meets the basic requirements for the facility is located at about a 5 minute walk to the south/west of the architecture school, beside the energy court parking lot. This large open site is flat, easily accessible on foot, or by car, and it is not privately owned. The city is planning to eventually extend Larch Street (located just across the tracks), which positions this building to potentially be a part of a greater urban development in the future. In fact, the small access road that cuts through the site is positioned ideally for this future connection, making the property even more reachable. Due to its proximity, size and accessibility, I believe that this property is the ideal location for a research and fabrication facility, in downtown Sudbury.

Endnotes:

Chapter 6: Laurentian University Wood Architecture Research and Fabrication Centre: Building Design

Similar to many of the buildings constructed at the Architectural Associations Hooke Park campus this design proposal applies experimental wood assemblies in the construction of the building. The double curving glue laminated beam structure previously discussed is applied as both a structural and architectural roofing assembly.

Through the process of sketching, and after multiple iterations, a canopy like structure is created by these double curving beams. By having multiple rows, and sizing them differently, the potential of this new system is demonstrated. It creates an aesthetic which is strong enough to illustrate the potential of mass timber. By linking each beam together, an interesting wave like pattern is achieved, creating a large, continuous canopy, for unencumbered work to occur below it. This will allow for long term versatility. Spaces can be constructed and dissembled to suit its most current needs. When necessary, extensions can be made, or rooms can be added, so that as technology progresses, the facility will be adaptable, thanks to this large roof canopy.

Figure 80: Sketching exercises that explore form, driven by the natural shape of the double curving truss system
Figure 81: Select sketches from design exploration
Figure 82: Sketching
**Figure 83:** Further iteration that relates more closely to the final design. It represents a strong division of space, however does not utilise the wood structure to its fullest potential.
In order to layout work spaces below, the facility is broken into two main categories, which will then be informed by the programmatic elements. Simply, the facility requires a clean space and a dirty space. The clean space serves to protect the more sensitive elements of this type of facility. Electronics (such as computers, 3d printers, and microcontrollers), guests and dry storage require protection from dust, moisture and noise. This therefore requires physical separation from a work space that more traditionally resembles a wood shop.

With these two categories in mind, programmatic elements can be separated between the two. The clean lab, meeting room, reception area, personal storage, washroom/change room and some office spaces will be located on the clean side of the facility. While on the dirty side, large machinery, build/work spaces, loading area and storage will be situated.

The building is then broken down into 5 distinct parts.

The first, is the reception. The idea is to locate this part closest to the street. When examining the site, it makes the most sense for it to be positioned in the North/West most part of the site. This will create the first step for an urban street front, while also providing space for future developments in the neighbouring properties. Additionally, by locating it in the corner of the lot, the building becomes more accessible to pedestrians walking to the facility. With the unique canopy structure, it is important to highlight it when entering the reception. As individuals walk in, they are treated to a large curtain wall, which creates a visual connection that pulls your attention into the facility. Behind the reception, washrooms and personal storage are situated behind a dividing wall. This layout allows people to walk in, be welcomed, and choose to get changed, or move into the next part of the building, which could either be a dirty space, or a clean space.

The second part, is technologically driven, advanced robotic arms and a clean lab inhabit this area. They are positioned here to highlight the innovative digital fabrication research. Visual connections are made again by positioning the interesting technologies in locations where it can be easily seen from outside, and from the reception. Next, the clean lab will feature two office spaces, in order to accommodate the faculty members with interests in digital fabrication. It will also have general
Figure 84: Closeup image of roof canopy construction in the structural model
Second Floor Plan

Legend

1. Reception
2. Lockers
3. Washroom
4. Elec/Mech Room
5. Work Space
6. Storage
7. Offices
8. Climate Controlled Storage
9. Outdoor Wood

A. Technology Lab
B. Offices
C. Digital Fab Space
D. Meeting Room
Figure 85: Floor Plan
Figure 86: Street perspective
Figure 87: Overhead view of the structural model
Figure 88: Perspective of the entrance and outdoor build space

Figure 89: Interior perspective
work stations and a room for equipment that produces large amounts of noise. A meeting space is located within this lab as well. This will provide an interesting connection to the entire facility, for guests to enjoy. The final design element with the lab is to raise it high above the floor. This space is so different to the rest of the facility, that it should be located on its own elevation. This difference will also be communicated in its material palate. Materials that represent sterility and cleanliness, which pushes the notion further. The size of this part of the building is driven by the program, to meet the needs of the objects inside it.

Third is a work space. Work tables, floor space, general machines and tools are located in this area. It would be central to the facility, making it easily accessible from any part of the building. It is also the largest part of the facility, to accommodate the space required by all of the equipment.

Fourth is open floor space. It is intended to have a large open area to accommodate big build projects. An overhead gantry sits in this area, it would be used to move and support heavy equipment and projects. By introducing a large opening to the one end, large trucks can drive into the facility to unload material, or be loaded with project via the crane or fork lifts.

Lastly, the fifth space is dedicated to storage and office space. Storage racks and shelves are out in the open and ready to accept materials. There is also a climate controlled storage room for the more sensitive resources. At the other end, are additional offices for faculty members who spend most of their time at the workshop.

These five spaces serve specific functions. To represent the divisions, the roof varies in size and shape. The columns that support them further help to communicate this idea. The glulam support extends up and branches out to hold this tree like canopy in place. This result is a clear line between each space, without hindering the flow of travel between.

Outdoors, the canopy provides a large sheltered work and storage space for additional projects to occur. Additionally, near the entrance, an opening to the large payload robotic arm creates a nook for work, and events to be hosted. The south side of the building has a driveway for a
handful of cars to park, while also providing a driveway for trucks to back into the large open floor space and gantry crane. To the eastern side of the building, trees are planted to help re green the site. These trees serve to also inform the research inside the facility. Similar to Hooke Park, these trees can be harvested once fully grown, to be incorporated into research projects. Should the canopy or the facility require an extension, the structural grid is oriented to allow for additions to be added in this direction. There is a wood drying shed in this small forest, which follows the same architectural language as the wood canopy. Then to the South/ Eastern most point, located at the south-east of the site, solar panels provide the research facility with sustainable energy.

The positioning of the facility in the energy court creates the potential for the building to become a landmark building. With the consideration of the Larch St. extension in mind, it will act as the bookend to this road, before it reaches its connection to Larch St. The wood building suggests through a visual connection, that the city centre extends beyond the train tracks to the west. Additionally, the choice of construction materials, along with the re-greening of the site, would further symbolise the city, and its built environment are progressing towards a more sustainable future.

Construction:

As demonstrated by projects completed by StructureCraft and Kauffman Zimmerei und Tischlerei, prefabrication is full of opportunity. Companies like these make the complex structure of the research facilities wood canopy possible. Since the trusses for the canopy are designed to be transported, they can be brought to site, and quickly installed. To further develop the idea of prefabrication, the walls and floor (for the clean lab) are also built ahead of construction. This would create a simple assembly, which would require much less time for onsite construction than traditional building practices. Each aspect of the building can therefore be considered as a component, whether that is a wall, floor, or roof module.

This notion of prefabrication is an opportunity for an improved construction methodology, especially in northern climates. Regions such as Sudbury experience long and cold winters, which hinders the construction industry. It is not uncommon to see projects stall in the late
Figure 90: Path of travel plan between the McEwen School of Architecture and the Wood Research & Fabrication Facility

Figure 91: Path of travel plan which includes the Larch Street extension and additional re-greening of the Energy Court
Figure 92: Site & concept model
Figure 93: Site Plan
Figure 94: Image of the structural demonstration model
Figure 95: South elevation & section
fall due to the cold, construction is forced to wait until the spring thaw to resume building. One of the reasons is that materials, membranes and adhesives often require a specific climate controlled environment for proper installation. Through great effort and expense, warm spaces can be fabricated around a project, should a tight timeline require it. However, the situation is less than ideal. By fabricating architectural assemblies inside of a specialised facility, builders are provided with an ideal working environment for both themselves, and the materials they work with. Proper lighting, climate, electricity and tools are more easily accessible in a controlled space.

Similar to Hooke Park, The Embodied Computation Lab and the Autodesk BUILD Space, thoughtful technological integration such as robotic arms, could potentially even work alongside tradespeople to facilitate fabrication, while also raising the level of precision. Additionally, building indoors will allow construction to continue during the cold season.

The Structure Craft facility is an example that supports the argument for prefab. As previously mentioned, in just 5 days, its entire new 50 000 sq. ft. facility was assembled through the utilisation of this construction methodology.

Additionally, as seen in both the Structure Craft Facility and the Kauffmann Zimmerei Und Tischlerei Wood Modules, prefabrication offers the opportunity for complete assemblies. Finished components that feature all of its systems (i.e. finishes, insulation, structure, membranes, electrical, plumbing, etc.) can be prebuilt and shipped to site for installation.

Lastly, prefabrication offers environmental benefits as well. Traditional on-site construction will often generate waste, whether it is through off cuts, the production of dust particles, the removal of protective wrappings and/or excess material. Building indoors offers the benefit of trapping all this waste, which can then be collected and disposed of properly, or whenever possible even reused. Additionally, with very careful planning through the design process, waste could be entirely eliminated.
With all of these concepts in mind, prefabrication is an intelligent construction approach in Northern climates. It offers the opportunity to extend the construction season throughout the entire year. The sensitivity of construction and the limited amount of time available on a job site benefits from producing components indoors, while also minimising waste. Companies around the world already have business models built around the concept of prefabrication. They have done projects that serve as evidence that it is an ideal construction methodology for cities such as Sudbury.
Chapter 7: Conclusion

Concerns about climate change and the growing awareness of the importance of environmentally conscious design, has led to the re-emergence of timber in the building industry. Technology has developed to the point that wood construction can perform, in many instances, to a similar or higher level than steel or concrete. As a result, 21st century architecture is utilising wood as a sustainable, carbon sequestering alternative to non-renewable materials. There is a present need for the development of an environmentally conscious building industry, which demands for the development of wood technology, and in turn, current construction methods. A fundamental change is on the horizon.

Through a study of existing building construction wood products, along with my own study of architectural wood assemblies design and fabrication, the development of wood engineering technologies is examined. Traditional timber logs transformed into dimensional lumber to ease the assembly of spaces and buildings, which then evolved into other products such as plywood, oriented strand board, wood l-joists, glue laminated beams and cross laminated timber to name a few, have all emerged to serve a purpose. Some of these were created more recently than others. My own personal experimentation in double curving glue lamination serves to argue that there is still potential for additional growth in the material. Therefore it is crucial to build facilities in universities with the intent on advancing wood applications in the construction industry. Applied research in emerging wood products, wood structural systems and insulated roof and wall assemblies along with robotic wood manufacturing techniques are all essential, toward advancing wood as the predominant construction material in the 21st century. The McEwen School of Architecture is focused on the values of making and design-build, and thus, a specialised facility is necessary.

The design of a wood research facility is based on a series of six case studies of leading architecture research and fabrication centres around the world. Each of these were chosen, as they represent a unique typology and scale. In academia, facilities vary from the very large Hooke Park and John W. Olver Design Building, to the relatively small, but comparable Embodied Computation Lab at Princeton University.
Industrial building examples vary from a concentrated focus on wood, like at Structure Craft or Kaufmann Zimmerei Und Tischlerei, to a greater interested in technological development at the Autodesk BUILD Space. Each of these facilities are generally working towards the development of wood and technology.

The case studies served to develop a building design proposal for a wood research and fabrication centre at the McEwen School of Architecture, at Laurentian University. Similar to several case study examples, the building applies an experimental wood assembly in its design. The form of a large curving canopy is achieved through an assembly of prefabricated double curving beams, serving as an important structural element and demonstration building.

The buildings assembly is a proof of concept for wood prefabrication and it demonstrates the versatility and potential of the construction methodology. Additionally, the wood research facility is an example of future wood construction in northern climates.


Epp, Gerald. Interview by Marc Bartolucci. e-mail. October 29th, 2018


Joseph Mollica, Zachary. Interview by Marc Bartolucci. e-mail. November 6th, 2018


Wartinger, Grey. Interview by Marc Bartolucci. e-mail. October 31, 2018