Consider The Kayak

by
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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

In ignorant disdain towards the progression of globalization, I have adopted the plastic kayak as a microcosm of the cultural ethos of the design of our surroundings. To counter the abundant mass manufactured kayak, I am fabricating a traditional arctic qajaq (Inuit spelling), to fully understand the qajaq and its history.

Through the design, construction, and use of the qajaq, I expose the crucial elements that form the watercraft. Combining contemporary tools and materials, I design and fully assemble two more iterations of the qajaq. From wood, to metal, to plastic, I learn the process of design with the intention of construction in today's society.

The wood skin-on-frame qajaq reveals the limiting factors of design: the influence of economics, tradition and its place in contemporary design, ergonomics, form-focused versus frame-focused construction, and the proper expression of design tectonics. The metal skin-on-frame qajaq is a study into limitations of material exploitation. I begin to optimize the fabrication process to create a streamlined assembly suited to a globalized marketplace, while maintaining the same spirit of the traditional qajaq. It is designed to rival the durability, cost, weight and ease of fabrication of a contemporary plastic kayak with the beauty of a traditional qajaq. The plastic skin-on-frame qajaq is a structural improvement on the metal frame and is quicker to assemble, demonstrating how using new tools with an old practice produces quality work.

In a culture that relies on mass fabrication, designing and fabricating a qajaq in this iterative manner reveals the importance of design only in contrast to the commonplace.

Acknowledgments

If you're reading this thesis at all, thank you. Also, to those of my friends and family who supported this adventure into boats building while knowing that I had no prior knowledge of boat building or water sports of any kind, thank you. I am simply elated that my kayaks are not death capsules.

To my parents, Michelle and Frank, thank you for your support and patience. Also, through the majority of this extended process, I appreciate you never asking me 'why', or 'how' or 'when'.

To my supervisor, Donald McKay, and committee member, John McMinn, thank you for your input and sharing your wisdom and intellect.

To my honorary thesis advisors, Dan Jessel and Heinz Kroller, you both had great influence on the evolution of this work. Thank you for sharing so much of your skill and knowledge, and exercising patience when I demonstrated my occasional lack of common sense.

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Preface

"What the hell is a kayak
and where did it come from..."

...those were my thoughts while I sat on a park bench along False Creek. It was a sunny day in Vancouver, cyclists and runners passing behind the paved path, and kayakers floating alongside the shore. The kayaks were colourful open-top plastic watercrafts, which each user enjoyed.

As for myself, water-sports never drew my attention. Most likely because I am only capable of staying afloat in a kiddy pool. My primary exposure to kayaks was watching Olympic events dedicated to the sport. However, I understand the appeal; how the bow split the water, the tempo of the paddling, and the trailing ripples in the water. The kayak as an apparatus is mesmerizing.

Unlike the fibreglass or carbon-fibre kayaks commonly seen in the Olympics, most of the vibrant coloured Vancouver kayaks were scuffed from inexperienced kayakers. I sat and watched as some paddlers scraped the plastic boats against shoreline rocks and a few younger paddlers used their kayaks as bumper boats. Corporate rental companies store the kayaks in stacks along the river, available as "*standing reserve*" for eager 'outdoorsy' Vancouverites to rent from a 14-year-old high school student summer employee wearing a tank top and flip-flops.

How many of these rented paddlers know the history of the watercraft? I certainly do not. It is easy to blame globalization and the mass production of goods for the disconnect between person and thing. I do not intend to diminish the importance of globalization and global trade for today's economy. It as a solution to sustain the world's population is crucial. Although, living in a globalized world where sharing traditions is facilitated by world trade, the internet, and e-commerce there is a stagnation in the evolution of designed goods.

Something as simple as a Japanese multipurpose knife, a santoku, has evolved to its current form today through centuries of experimentation with form and material. Since it is now feasible to export these knives to foreign countries, after the first couple of years of knife shipments arrive, any knife that resembles a santoku but has a slight modifications is

labelled as an inauthentic Japanese santoku by foreign, self-proclaimed expert consumers who write bombastic reviews online. A simple linguistic example of this is Quebec French vs. France French. Any idea of tradition inhibits progression, especially once the item in question leaves its place of origin.

The stagnation in advancements is a concern, especially the realm of mass production, where corporations design for the masses rather than for a local community. Fortunately, technology has become the new home for customization. New tools creating new practices will end stagnation. Contemporary kayak design is not immune to the influences of mass production and globalization. The traditional qajaq has evolved from driftwood and sealskin, to a rotationally moulded plastic.

Here, I analyse the hidden or less obvious aspects of the contemporary kayak, including historical material properties, form, fabrication methods, and economics. This establishes a baseline so I can recreate a traditional skin on frame qajaq. Assessing the outcome, making changes where appropriate through prototyping, and design reiteration, I will make a kayak more appropriate to the one currently in use in Vancouver's False Creek.

Wood

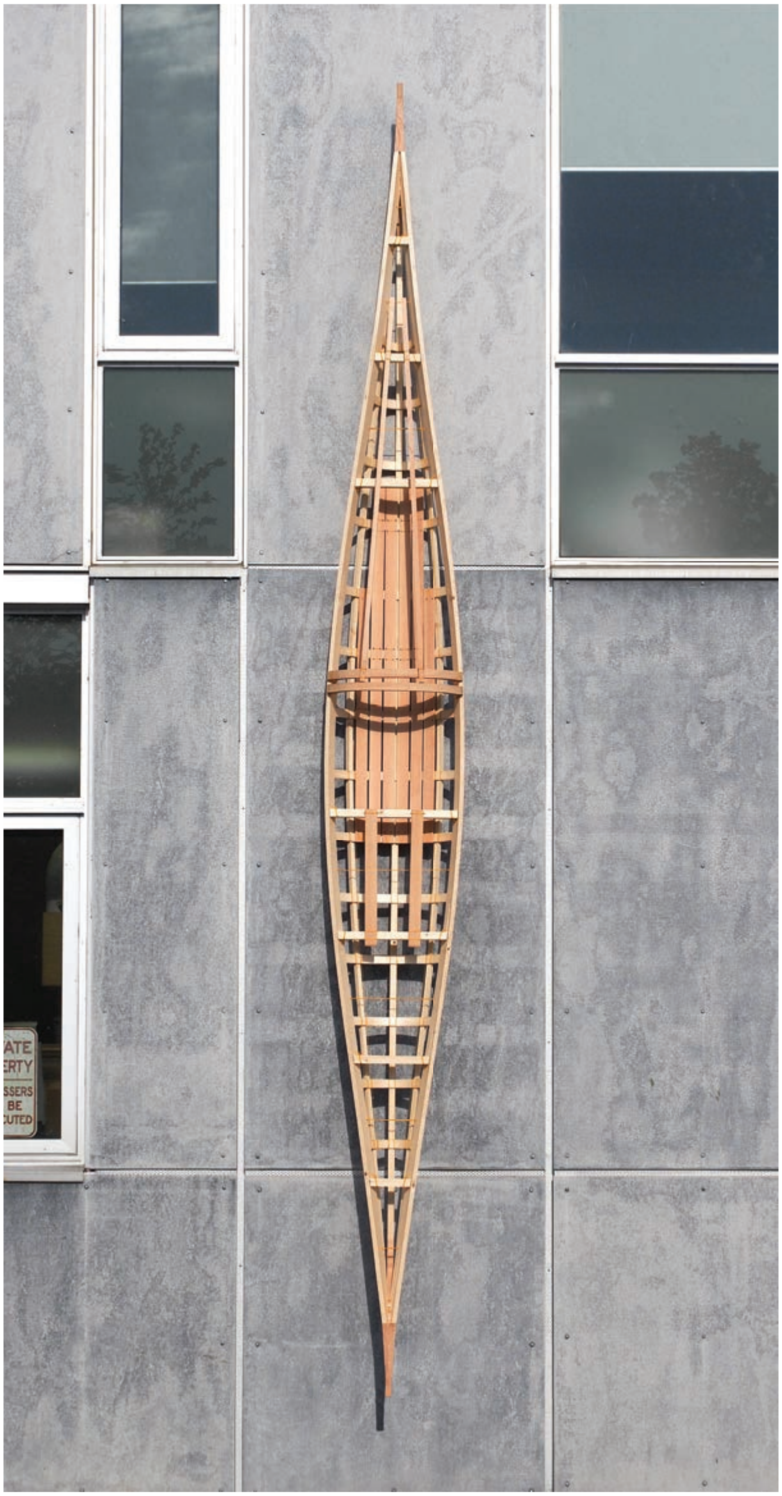


Figure 1.01

Figure 1.01
Wood frame kayak. Top view of skin-on-frame-kayak resting against the architecture school.

Figure 1.02
Measuring the length of a kayak. Three fathoms (arm spans) long will determine the overall length of the gunnels.

Figure 1.03
Map of kayak variations. Across the entire arctic, each area had specific variations and design differences based on site specific materials.

Wood

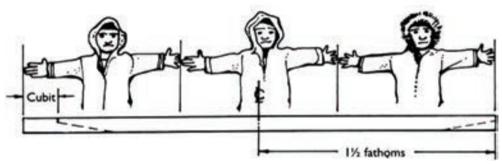


Figure 1.02

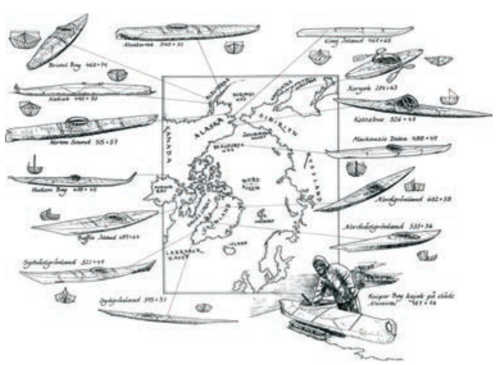


Figure 1.03

The qajaq (Inuit spelling) is a traditional boat, with a design passed down generationally through an oral indigenous arctic culture. As such, the qajaq was a product of anthropomorphic design, design by the multiplication of physical measurements. For example, the length of a traditional Greenlandic qajaq (from bow to stern) is three times the length of the user's arm span. The width is the dimension of the user's hips plus their two fists. While standing, the height of the user's vertically outstretched arm to the floor is the length of a paddle. A qajaq is a physical translation of the user's proportions into craft.[1]

Envisioning the body as a proportional system is not a unique concept. The most famous example is Leonardo da Vinci's Vitruvian Man[2], an illustration showing the proportions of a human body inscribed in a circle. Another pertinent example is architect Le Corbusier's Modulor Man, a rendered silhouette of the human figure with a graphic scale dividing the body through proportions.[3]

In this fashion, every qajaq being unique - each craft varies based on user proportions. In contrast to the contemporary kayak, one that satisfies the median consumer expectations, established by the parameters of mass production, arctic people traditionally made a qajaq from driftwood members collected along an icy coastline. The driftwood components lashed securely using sinew or cord. The final frame is skinned with multiple seal or moose hides. "In the Arctic, it could take up to a year to build a boat using traditional methods...where most of this time was [dedicated] to acquiring materials and processing them into a useful form."[4]

The design and process of building a qajaq are bound together and to understand the traditional qajaq, is to make one.

To begin at the beginning, I needed to learn how to build a qajaq. I am not of indigenous heritage, nor do I know of a qajaq builder willing to spend that much time with me. Second best to verbal instructions is a written transcript. Through multiple blogs, I came across a construction manual called "Building Skin on Frame Boats" by Robert Morris. The

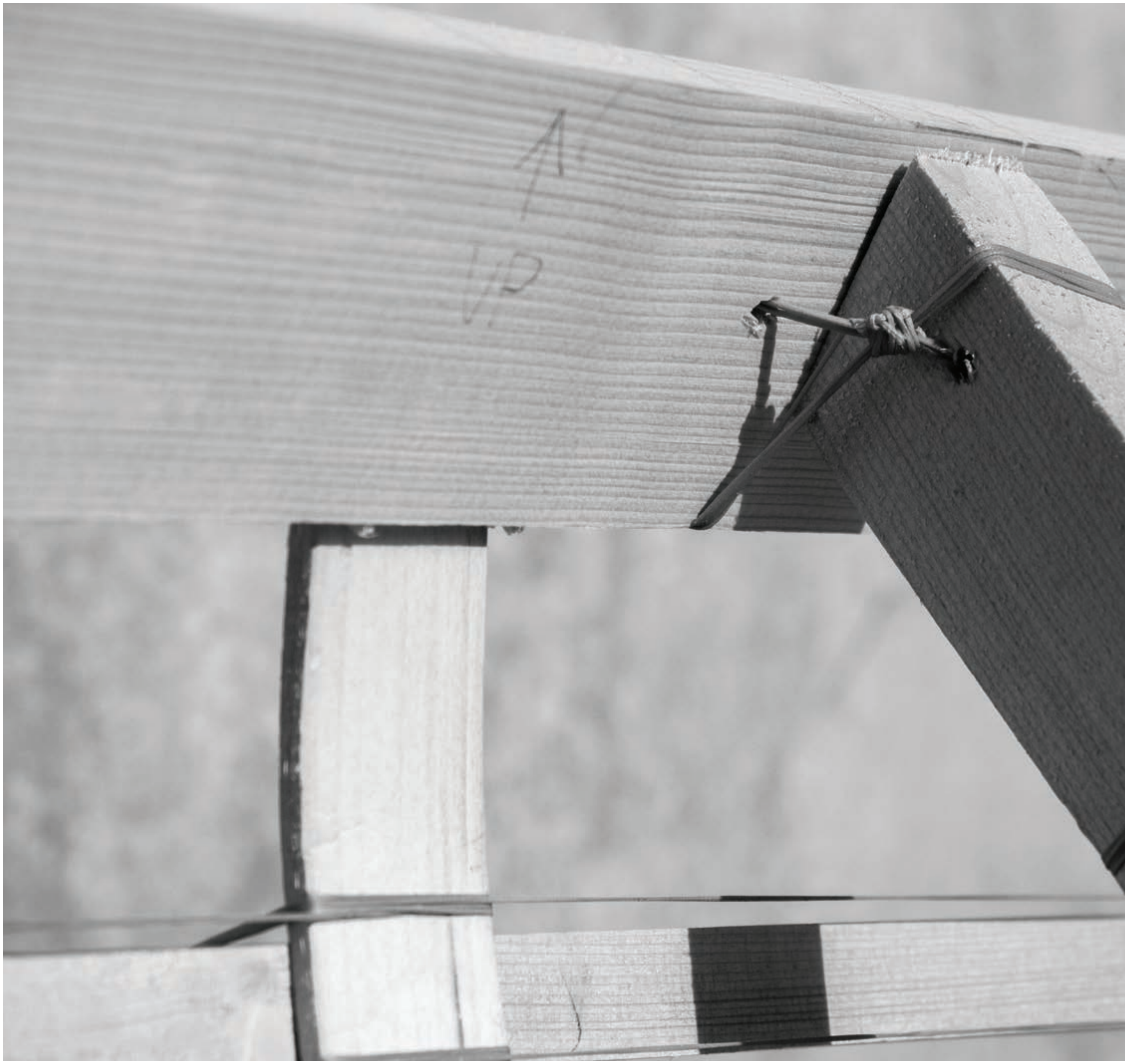


Figure 1.04
Joint connections. This image shows the lashing of the deck beam to gunwales connections and the lashing and dowel connection of the deck stringer to deck beam. This photo also shows the pencil marking which aided in keeping consistency with the two gunwales cut from one piece of wood.

Figure 1.05

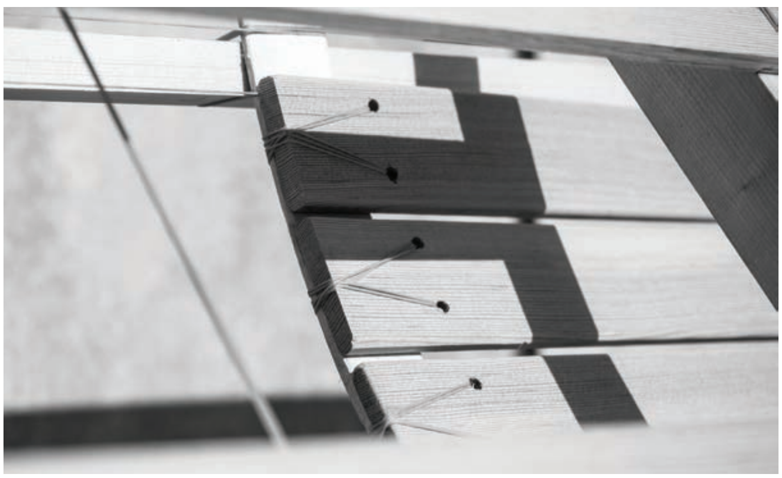


Figure 1.06

Figure 1.07

Figure 1.05

Gunwales imperfections. It is difficult to rip in half what is essentially a two by four board on edge with a circular saw when the blade only goes down halfway. The variances in the top and bottom cuts can create pits or voids if misaligned.

Figure 1.06

Decking lashing. After some time using lashing, I came to understand it fairly quickly. I can then create interesting paths for the string to rest to create visual interest.

Figure 1.07

Masik and knee brace connection. Most hole drilling uniformity was done using fingers to measure. For example, one figure width away from an edge, or two holes three finger widths apart. When it comes to drilling on diagonals, it is challenging to maintain a consistent angle for each hole. This variance creates different size surface areas of the dowels after being cut. Taking the time to create a jig that maintains a consistent angle would have been wise.

Figure 1.08

Lashing. An example of how to lash the gunwale to the deck beam.

book puts an emphasis on building traditional style qajaqs using building materials found at a local hardware and lumber store, all the while maintaining the spirit of tradition fabrication throughout.

Building a qajaq starts with demarcating a system of measurements on a length of 2" by 12" wood board. To find the ideal board, I went "urban beachcombing" as Robert Morris describes it. This involves rummaging through a stock of rough sawn lumber, board after board of nominal 2" by 12" by 20' spruce, isolating promising clear pieces from those with many knots. To come across a clear straight grain spruce board in a construction lumberyard is no small task. To find one acceptable was a moment of joy.

Once I had the lumber indoors and acclimatized to room temperature, I could move onto the next step: dressing the wood, that is, reducing the piece of wood to its final size. I started by ripping the board along its clearest section, down to a nominal 2" by 4" board, which will become the heart of the qajaq from which I will cut the gunwales.

My options for ripping the wood are portable power tools or hand tools. I did not see any advantage of spending extra time woodworking without the aid of electricity. It would not provide any more information into what makes a traditional qajaq. If anything, the frustration of not having accurate cuts nor the body strength to plane long boards would expose more questions about the quality of craftsmanship, rather than the quality of the watercraft. In general, power tools mask inability and lack of skill[5], but for the purpose of this build, the learning curve is already steep, without the added stresses of becoming a competent powertool-less woodworker. In assembling the components of the wood skin-on-frame kayak, my aim is to achieve balance between new tools and old practice.

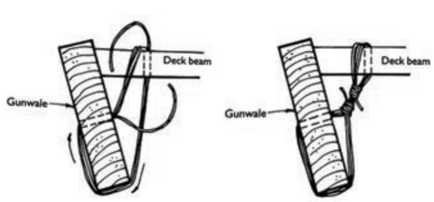


Figure 1.08

With the gunwales in place, the next step is to install the deck beams. Each deck beam to gunwale connection is fit with a peg or dowelled joint rather than a mortise and tenon. Additionally, there is not a trace of glue in any connection to allow for flexible joinery that twists under stress at the connection, rather than across the members. Lashed joinery is a crucial element keeping the qajaq together. The fastening method need not be any more complicated. Lashing is an old technology that requires very little skill...even children can learn. However, prior to learning qajaq building, children of indigenous arctic cultures are first taught about the kayak

Figure 1.09
Shadow play. Using the school of architecture as a backdrop, the shadows of the kayak monochromatically show the complexity of the frame.

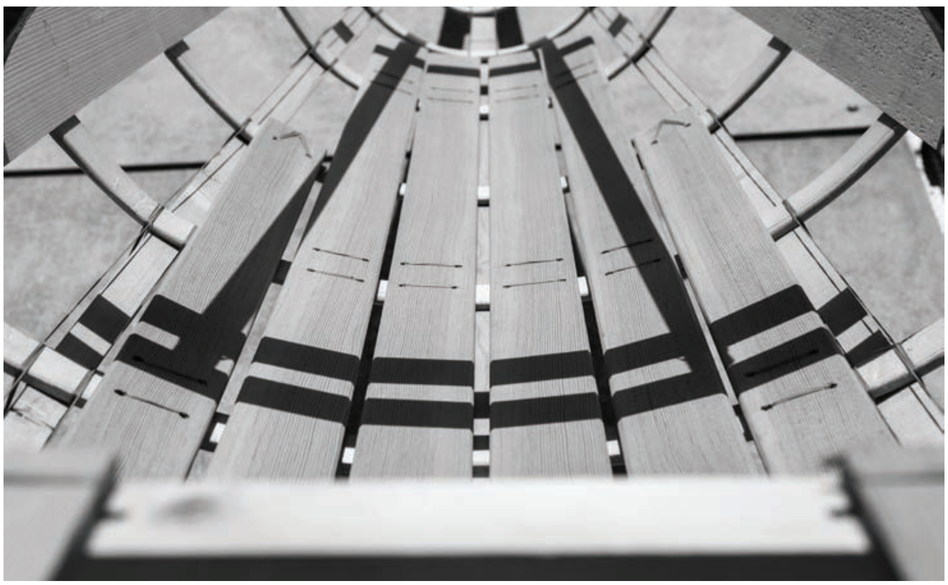


Figure 1.10
Decking. Douglas fir decking lashed to ash ribs slotted into spruce gunwales.

Figure 1.11
The chosen one. The ash tree that became the ribs of the wood frame kayak.

as a cultural swimming apparatus. Today, young Greenlandic people first learn kayak skills on land using tensioned ropes to practice the movements involved in rolling a kayak, a crucial part of mastering the art of paddling.[6] Today Greenlanders and others from around the world celebrate this tradition during Greenland National Qajaq Championships. This event is essentially the Olympics for traditional paddling. Most events include some element of rolling. Today recreational kayaks are designed for stability and ignore rolling as an integral aspect of the sport. This alludes to a defining difference between the function of a qajaq and a kayak. Arctic people use the qajaq as a swimming apparatus whereas the contemporary kayak is used as a flotation device.

The ease of construction may have something to do with this separation in uses. It is documented that northern people would carefully curate the ribs of their qajaq from naturally bent part of tree branches. To further compress the wood for the bend, chewing on the fibres was common practice. So with a planar frame comprised of two gunwales and deck beams complete, my next step is to locate the ideal wood species for bending ribs. Luckily, the construction manual I follow does not include chewing wood. Rather, steam bending is the wood shaping method of choice. The ideal wood for steam bending is green, white oak. That is, white oak that has not been kiln or air-dried (although rehydrated air dried white oak would also work.) White oak has been the preferred wood of shipwrights as well as coopers. Typically, any object trying to keep a liquid in or out is made using white oak. This is due to a tight, non-porous grain structure that prevents water from seeping through the wood. The grain structure also prevents failure when steam bending. After calling around, searching local classifieds, and talking to Dan and Heinz, I decided to cut down my own white oak tree. My parents live on land with a forested area. I tried my best to identify a white oak against the other tree species. Unfortunately, this is all happening at the end of February when the hardwood trees have dropped their leaves and the only identifying characteristic is the textured pattern of the bark. I analyzed tree bark against an image of my cellphone, comparing the ripples of one tree against the other. I decided on one. I was fairly sure it was a white oak…there were even white oak leaves on the forest floor. It was tall and skinny, with relatively few offshoot branches. This would mean clear straight grain wood, perfect for steam bending.

Figure 1.12

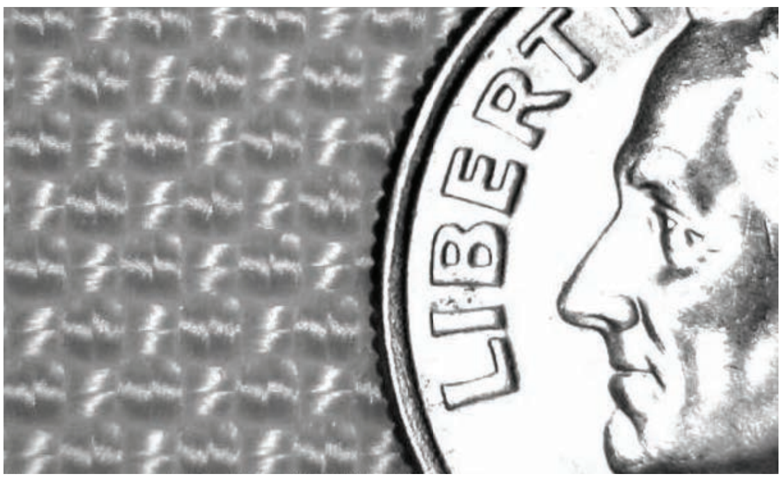


Figure 1.13

Figure 1.14

Figure 1.12
Nylon cloth weave in view with U.S. dime by George Dyson. 7 oz. plain weave. Loose enough to drape acceptably and tight enough to hold a seam. Shrinkage is moderate, and well suited to lightly-framed wooden boats.

Figure 1.13
Nylon cloth weave in view with U.S. dime by George Dyson. 12 oz. oxford weave. Dense, tightly-woven material, will hold a seam exceptionally well, in a narrower width with less waste for covering narrower hulls.

Figure 1.14
Nylon cloth weave in view with U.S. dime by George Dyson. 15 oz. twill weave. The twill weave drapes easily, and holds coatings well.

Figure 1.15
Map of southern Ontario. The two main options traveling to the Collingwood area from Cambridge, Ontario. Taking the faster 400 series freeways or the less busy, slower speed back roads. A time difference of about 30 minutes driving the respective speed limits.

I started with a large bow saw, then quickly switched to an axe. The downward force of the tree on the saw blade made it difficult to pulsate. Once I fell the tree, (arborist lingo is uneducated to say the least) I cut a manageable portion off the bottom and brought it to the fabrication lab at the school of architecture. With the help of the Dan in the workshop, I milled this beautiful white oak into straight grain strips, ideal for steam bending the ribs. From the photos of white oak online, despite it being called white, I recalled it having a more grey hue. This oak is white. Glaring white. It also doesn't really share any other characteristics of a white oak grain pattern. Well then, what tree did I cut down in vein? Answer: Ash. Given that the Emerald Ash Borer decimating the population of ash trees in North-Eastern America, of all the trees that I could have cut down by mistake, an ash tree is probably the safest. Luckily enough, ash is another temperate hardwood that excels in steam bending. After the ribs were steam bent with a typical fifty percent success rate, I could continue with the steps outlined by my guidebook. This included attaching stringers to the ribs as well as constructing a steam bent cockpit ring. With the frame complete, the final step is to wrap it with a fabric. I chose an eight-ounce nylon with an oxford weave. Once loosely draped, stitched, and then soaked with water, nylon has the unique ability to shrink up to fifteen percent of its initial size, leaving a taut but not overly tight skin. Unfortunately, nylon itself is not waterproof without a waterproofing layer applied to its surface. I coated the skin with seven layers of a ultra-violet resistant spar varnish mixed with a white oil based primer giving the qajaq an off-white shade. Last on the list of steps; test it.

I drove to my aunt's lake house near Wasaga beach with the completed 17' long kayak strapped to the top of my mom's rackless 2007 VW City Golf. I thought it best to take the back roads up from Cambridge rather than the 401 Expressway. Even with the reduced speed limit of country roads, I worried about the qajaq catching wind and taking flight. I put away my ego and drove at minimum of 10km/hr under the speed limit at all times. The tie-down ratchet clamps straps cut through the wind with ease, while the protective plastic foam I laid on the roof of the car supplied the soundtrack for the trip with its vibrations. If the 2.5 hours of noise was not dramatic enough, the rain added an extra bit of chaos. On arrival at the cottage, the skies cleared and the water was calm, as if I was a part of a

Figure 1.15

Figure 1.16
Wood frame kayak. As clearly seen in this photo, some ribs steam bent with more grace than others. The spruce stringer is then lashed to the ribs with a continuous piece of string that runs the length of the kayak twice.

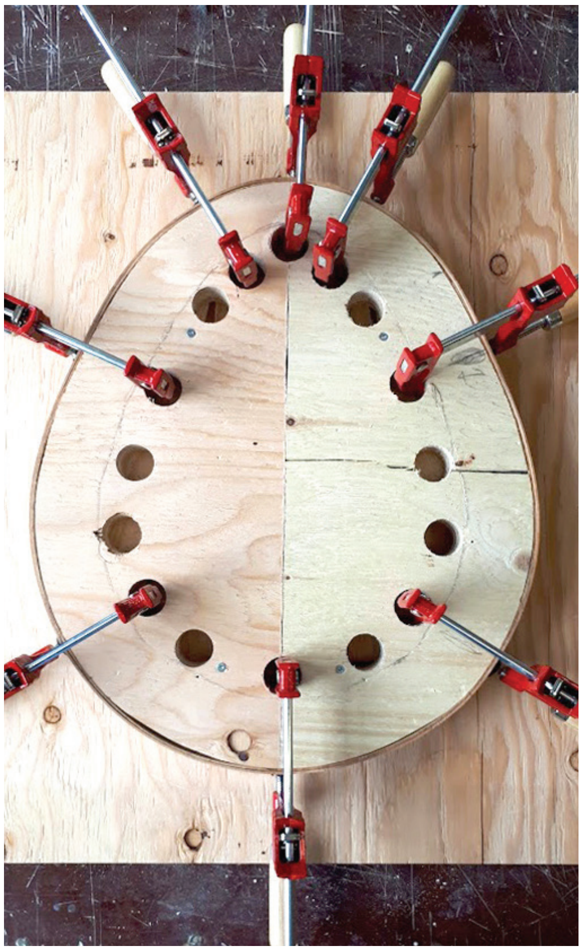


Figure 1.17

Combing or cockpit ring. The opening width of the combing is dictated by the width of your hips whereas the length is dictated by the opening of the built form. Multiple laminations of ash was steam bent around the form and glued to create the thickness.

Figure 1.18

Figure 1.19

Figure 1.20

Figure 1.18
Transporting the kayak. Strapped down to the top of the VW Golf using ratchet clamps, the kayak didn't seem extraordinarily fixed. It worked nonetheless.

Figure 1.19
Lower back cuts. If you flip the book upside down, my lower back looks like a different body region.

Figure 1.20
Knee cuts. Bare wood doesn't make for the most comfortable knee rest.

'90s Disney film with overdone pathetic fallacy.

Once the qajaq was free of restraints, I embarked on the maiden voyage, both for myself and for the new qajaq. After falling in the water over and over again in an attempt to enter the kayak for the first time, it floated. It also steered straight, was swift, and given its narrow width, it had excellent primary stability. I anticipated glaring issues that would justify a complete redesign of the old technology. Although I have never used a kayak, any failures would be apparent, and this qajaq performed well.

While using a qajaq, Robert Morris recommends that the user sits with legs straight and back perfectly perpendicular to the boat. After five years of sitting throughout my undergraduate career, my hip flexors and hamstrings are intolerably tight. Attempting to sit in this position for longer than 10 minute bursts is unbearable. I started adapting my posture to extend my time paddling. I leaned back against the unpadded backrest, and with my legs slightly bent, I pressed my legs against the also unpadded masik (the wood member creating the cockpit opening) all to relieve pressure on my hip flexors. The bruising the wood left behind on my legs and back showed my incorrect use of the qajaq, which is a trigger for my body to start adapting. Similarly, it is common for a person to feel pain in their tongue when learning a language.

Contemporary recreational kayaks have wide cockpits promoting a relaxed reclined posture, similar to the final position I found myself in. In turn, this reduces the use of the waist in the paddle stroke, with other muscle groups compensating for the transfer of energy leading to more fatigue in the arms and shoulders. As a society we have strayed from the traditional skin-on-frame design of a kayak - and for what? Not for performance, but for comfort. From the perspective of sports science, humans adapt for function. A clear example is a sprinter's body vs. endurance runners. From the perspective of technology, humans will adapt. The computer was integral to society in building today's material world, but only after we adapted our behaviour and learned to use and ultimately exploit computers.[7] It is the leisure, recreation, and ergonomics sectors of design that create objects in the interest of comfort. Humans will adapt, so long as the person deems the design worth adapting for. A kayak is an instrument; the same a bicycle, computer or a pen. After prolonged use of a pen, an indentation in your index finger forms where the pen sits.

Figure 1.21
Maiden Voyage. Arriving later in the day, the clouds cleared and the setting sun peaked through the clouds. This set the scene for the first use of the wood frame kayak, and the first time using a kayak in general.

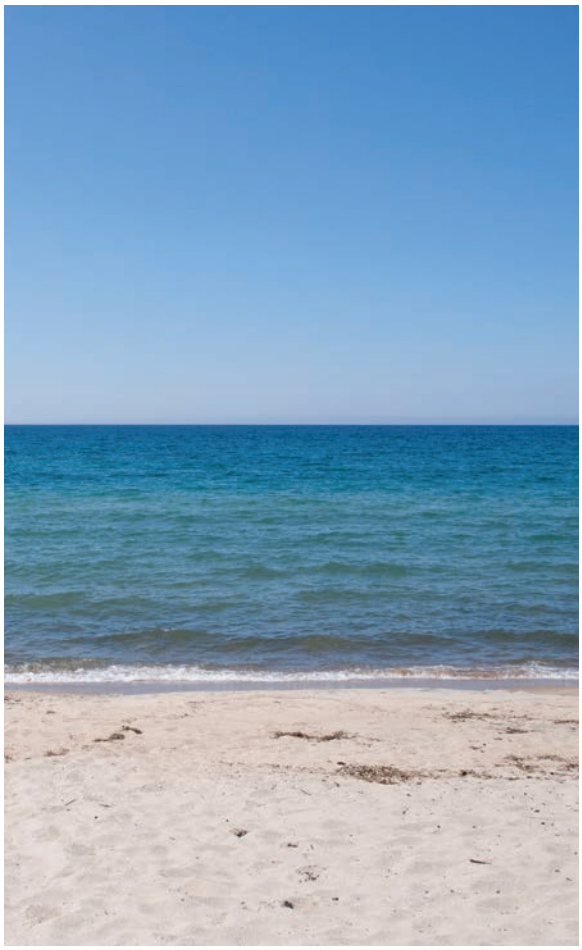


Figure 1.22
Yours to discover. Georgian Bay, where at one point, indigenous Canadians occupied the land using the similar technology to thrive in this ecosystem. The ideal location to attempt to use the historic skin on frame kayak.

Figure 1.23
The quintessential skin on frame kayak with user photo. A must-take photo showing the shear size of the craft. I know I look short, but I'm 5'10-3/4", 178cm tall.

Figure 1.24
Kayaking. Without lessons, or at least a friend to instruct, it is safe to say you can only learn so much about the act of kayaking from a book.

Figure 1.25
In use. Once I gained my "sea legs," kayaking was somewhat enjoyable. Especially if I ignore the muscle pain.

Figure 1.26

Figure 1.26
Wood frame kayak. Bottom view of skin-frame-kayak resting against the architecture school facade.

Figure 1.27
Rotational Moulding Machine Patent. Figure 1 of the US moulding machine patent number 3,829,272.

Figure 1.28
Bubble houses. Plans and elevations of the Wallace Neff bubble houses.

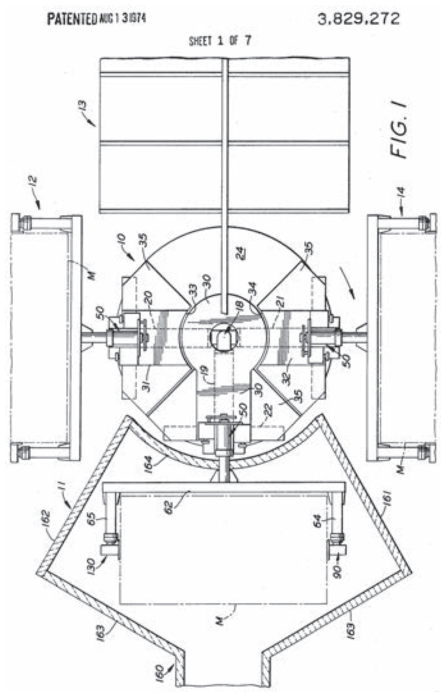


Figure 1.27

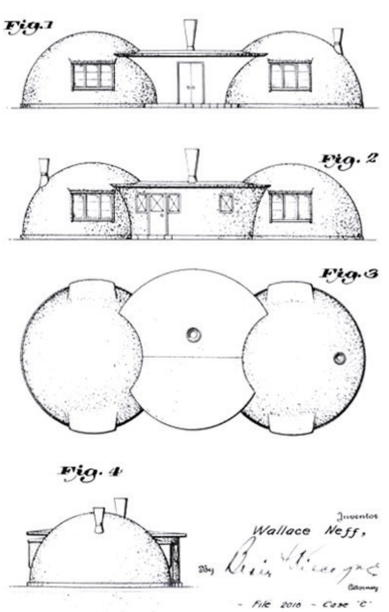


Figure 1.28

Instead of changing the apparatus to suit the modern body, the body should be given the opportunity to adapt to the apparatus, showing its formation as a reward. Once this evolution is complete, it then opens new avenues of discovery for change. This open loop iterative cycle advance the body and mind into new territories of experience.

Another influence in the departure from design of a traditional qajaq is a capitalist approach to the mass production of goods. A company planning to sell numbers of kayaks at low cost has to meet consumer demands. Large-scale production typically means avoiding time-consuming fabrication and complex design details, and instead marketing comfort as a selling point as an alternative.[8] In this business model, a new start-up kayak company invests a substantial amount in technology, rather than human labour, streamlining production and creating uniformity with as few errors as possible, while maximizing production and income.[9] For a kayak start-up, the sizeable technological investment is a rotational-moulding machine and a nickel mould of their kayak. With this investment in place, the only decision remaining for the manufacturer is what colour(s) polymer pellets to order.

The frame, as a critical element to the fabrication of a kayak, has been completely forgotten. Even expensive sea kayaks, close relative to the qajaq, are made using forms whose negatives are cut using a 6-axis CNC router from laminated plywood or MDF that is then covered in fibreglass.[10] This form-based construction through a filter of economic efficiency, may not properly fit the user, resulting in poorer performance than intended. In a kayak, sizing may not seem significant, at least to someone like former pre-qajaqing me. As long as I stay afloat, why does it matter?

Looking to another recreational apparatus may provide some clarity. Road bicycle manufacturers have frame sizes based on the person's interior leg dimension.[11] It would seem absurd to ask a 5'4" person to ride a bike sized for a 6'0" human. The rider would find discomfort in their back and shoulders, and would activate inappropriate muscle groups if the bike did not fit.

Repetitive uniform construction has been studied in many industries with varied results. Within architecture, there are countless attempts at rapid mass-produced invariable formed structures. Wallace Neff, a California based architect, designed a post-World War II neighbourhood of concrete bubble

Figure 1.29

Figure 1.29

Shadow play 2. Using the school of architecture as a backdrop, the shadows of the kayak monochromatically show the complexity of the frame.

Figure 1.30

Geodetic Mathematics. Calculations proving the structural capabilities of the four frequency dome.

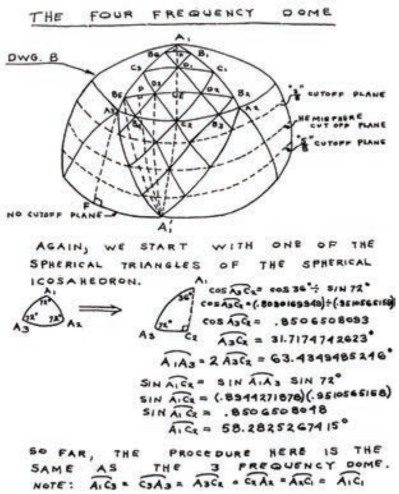


Figure 1.30

homes. The innovative structure was accepted by developers for their ease of construction and cost effectiveness. The outcome was a fascinating space-age development with dynamic interior spaces just as Neff imagined. But the buildings lacked proper ventilation, day lighting, and acoustically, the homes performed poorly. Inventive though they were, the general public was embarrassed by the homes. No one wanted to live in a concrete bubble, regardless of its construction methods.[12]

Preferably, Americans found geodesic homes more appealing than formed domes. They both create a similar type of a house but with two different constructions. One is dependent on the mould; the other is dependent on the details. The origin of architecture: a cave versus a tent.

Aesthetically, a frame provides an opportunity for intrigue and beauty that a mould does not. Each connection is an opportunity for detail. There is an understanding of how the object is assembled; it is not a magic bubble, birthed from a nickel cocoon. From kayaks to cars, our culture now conceals mechanical operations. [13] For example, the difference between the engines of a 1960's Mustang vs. a 2018 Mustang is striking. In the older mustang you can clearly see belts, filters and other mechanical parts. With some knowledge of engine repair, one could solve a problem with it. Today's cars have sensors connected to a computer metering its efficiency by running diagnostics. So it is crucial that only a specialist, and never the owner, fiddle with it. Thus we have the entire automotive industry designing engines encased in a plastic shield. Trying to fix anything on your own vehicle today could be a catastrophe. Well, it feels that way. The result of this is seen in the drop off of young people, especially men, interested in mechanics.[14] The souls of the 60's wave of the Whole Earth Catalogue tinkerers have now migrated somewhere else.[15]

The same people who grew up buying and fixing cars became the people hacking computers in the 2000's, and today they are the same people either embracing the optimization of technology through apps and social media, or ignoring it, categorised as hipsters, and trying to learn practices that technology cannot make obsolete. If today's digital landscape is the reincarnation of handcraft from earlier generations, it is important to once again become literate in the realm of tools that occupy our surroundings.[16] Understanding current technology while using history as a guide, I will gradually build upon the wood-frame qajaq while conforming to the parameters set by globalization. The goal is to increase the quality of the qajaq to make the craft more than a replaceable object, instead an apparatus with the same metaphysical qualities of the arctic qajaqs.

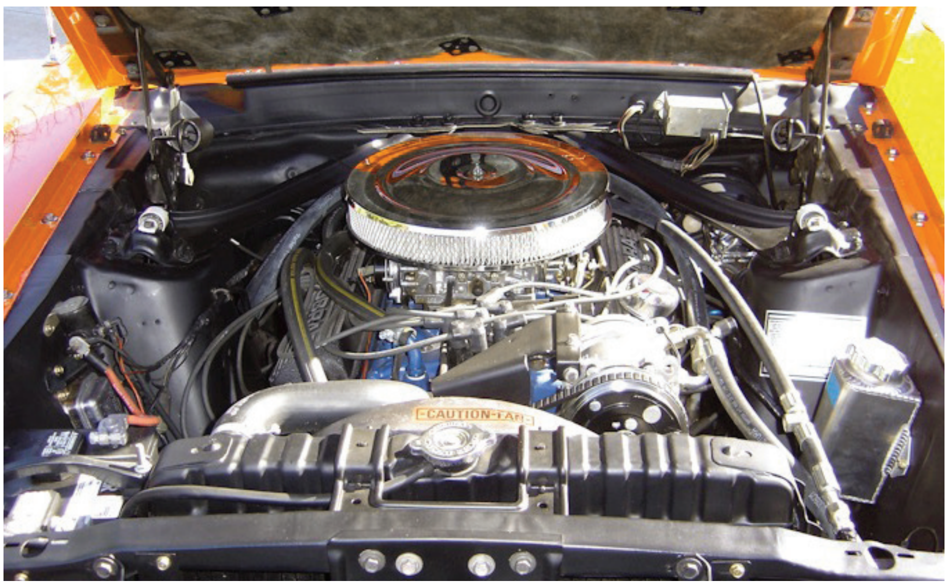


Figure 1.31
Engine 1. Under the hood of a 1970 Mustang.

Figure 1.32

Engine 2. Under the hood of a 2018 Ford Mustang. Note the plastic casements...everywhere.

Metal

Figure 2.01
Aluminum frame kayak.
Skin-frame-kayak resting against the architecture school facade.

Metal

What would be the incentive for someone to purchase a kit of parts or make a skin-on-frame kayak? Specifically, when contrasted with the simplicity of purchasing a rotational mould kayak. A new competitive design for a contemporary kayak must be at least up to par with its store-bought counterpart in a series of categories:

Durability
Weight for ease of transportation
Ease of fabrication and replication
Cost

With the added benefits intrinsic to a skin-on-frame qajaq:

Proportionally fitted to optimize performance
Aesthetically pleasing

Some aspects are easier to achieve than others. The traditional skin-on-frame wood qajaq I constructed met only one of the requirements.

~~Durability,~~
~~Weight for ease of transportation,~~
~~Ease of fabrication and replication,~~
✓Cost

Plastic rotational mould kayaks are more durable than a traditional style wood frame qajaq. This statement could be made through supposition, although, I gained this knowledge from experience. My third outing using the qajaq, I over tightened the ratchet clamps into my "MacGyver'd" car roof kayak system. The tension cracked the masik, the centre support beam adjacent to the knee brace, due to short grain in the wood. Luckily, the compression of the nylon skin held everything in place and clamp pressure with wood glue proved to be a quick fix. The simple truth is that a comparable plastic kayak would not have broken under such tension however; there

Figure 2.02
Stern assembly. Saddle stitching of aluminum parts.

ALLOY DESIGNATION SYSTEM FOR WROUGHT SHEET PRODUCTS

Aluminum alloys for sheet products are identified by a four-digit numerical system which is administered by the Aluminum Association. The alloys are conveniently divided into eight groups based on their principal alloying element. The first digit identifies the alloy group as follows:

ALLOY GROUP	PRINCIPAL ALLOYING ELEMENT	
1xxx	Unalloyed Aluminum	Purity of 99.0% or Greater
2xxx	Copper	Heat Treatable Alloys
3xxx	Manganese	
4xxx	Silicon	Low Melting Point Alloys
5xxx	Magnesium	
6xxx	Magnesium and Silicon	Heat Treatable Alloys
7xxx	Zinc	Heat Treatable Alloys
8xxx	Other Elements	

The last two digits in the 1xxx group correspond with the two digits after the decimal which indicate the minimum aluminum content. For example the aluminum content of 1060 is 99.60% minimum, 1100 is 99.00% minimum, 1350 is 99.50% minimum and so on.

The last two digits of the other groups are sequential numbers issued by the Aluminum Association to ensure each alloy is uniquely identified.

The second digit in all the groups indicates a minor modification of the basic alloy. For instance, 5252 is the second modification of 5052 alloy.

ALUMINUM TEMPER DESIGNATIONS

The temper designation follows the alloy code and is separated by a hyphen.

-F As Fabricated: Applies to products of rolling or forming where there is no special control over the thermal or work-hardening conditions. Since mechanical properties may vary widely, no limits have been assigned. This temper usually applies to sheet products which are at intermediate stages of production.

-H Strain-Hardened: Applies to wrought products which are strengthened by cold-rolling or cold-working.

-O Annealed: Applies to wrought products which have been heated above the recrystallization temperature to produce the lowest tensile strength condition of the alloy.

DESIGNATIONS OF THE –H STRAIN HARDENED TEMPERS

The First Digit

There are three different methods used to achieve the final temper of strain hardened material.

–H1 Strain Hardened Only: Applies to products which are strain hardened to obtain the desired strength level without any subsequent thermal treatment.

–H2 Strain Hardened And Partially Annealed: Applies to products that are strain hardened to a higher strength level than desired, followed by a partial anneal (or "back anneal") which reduces the strength to the desired level.

–H3 Strain Hardened And Stabilized: This designation only applies to magnesium-containing alloys which gradually age- soften at room temperature after strain hardening. A low temperature anneal is applied which stabilizes the properties.

The Second Digit

The amount of strain hardening, and hence the strength level, is indicated by a second digit.

-HX2	Quarter hard
-HX4	Half hard
-HX6	Three quarter
-HX8	Full hard
-HX9	Extra hard (the minimum tensile strength exceeds that of the Hx8 temper by 2 ksi or more)

Hx1, Hx3, Hx5 and Hx7 tempers are intermediate between those defined above.

The mechanical property limits that correspond to each temper designation can be found by referring to an appropriate aluminum standard such as the Aluminum Association Standards and Data or ASTM B 209.

The Third Digit

A third digit is sometimes used to indicate a variation of the basic two-digit temper.

HEAT TREATMENT TEMPERS

Alloys in the 2xxx, 6xxx and 7xxx groups can be strengthened by a heat treatment process. The aluminum is heat treated by carrying out a solution treatment process, in which the metal is heated to an elevated temperature followed by rapid cooling, then a precipitation hardening process (or "aging" process). The tempers are designated by –T followed by a digit. Some common –T tempers are as follows:

–T3 Solution heat-treated, cold worked, and naturally aged: Applies to products that are cold-worked to improve strength after solution heat-treatment, or which the effect of flattening or straightening is recognized in mechanical property limits.

–T4 Solution heat-treated and naturally aged: Applies to product that are allowed to age harden at room temperature following a solution treatment.

–T6 Solution heat-treated and artificially aged: Applies to products that are reheated to a low temperature following a solution treatment. This allows the metal to achieve its highest heat-treated strength level.

Figure 2.03

Chemical Composition and Properties of Aluminum Alloys. United Aluminum's tables explaining the nomenclature of aluminum and the advantages of different aluminum processing.

are durability benefits to a replaceable skin that outperform plastic. Unless you classify scratches, scuffs, and fading colour an appealing aesthetic, plastic kayaks do not age well. After years of wear you have the option of replacing the skin to keep the skin-on-frame qajaq looking and performing like new.

Throughout history, a natural step to improve the robustness of something while reducing weight is switching from wood to a metal alloy. Of the more readily available and economic alloys, aluminum has high corrosion resistance, and is less dense than steel. This made it a clear choice for the fabrication of naval vessels. There are eight groups of aluminum, each one having different properties based on percentages of various additives to the base aluminum. For elements that require high corrosion resistance, metal alloys with a high percentage of magnesium are commonly used in practice.[17] If I were paddling in the False Creek in Vancouver, overtime, the saltwater would corrode the frame of the kayak more than fresh water. With that in mind, for optimal frame performance and durability, I should select an aluminum group with the highest corrosion resistance. A high magnesium content in an aluminum alloy adds to the corrosion resistance of the metal. Thus, because of its 4.5-5.6% relative magnesium content, 5056 aluminum of the fifth group would be the most appropriate aluminum alloy. Next would be to select the tensile strength of the selected 5056 aluminum alloy.

Tensile Strengths

Hardening	Ultimate MPa (PSI)	Yield MPa (PSI)
O	195 (28000)	89.6 (13000)
H32	228 (33000)	193 (28000)
H34	262 (38000)	214 (31000)
H36	276 (40000)	241 (35000)
H38	290 (42000)	255 (37000)

5056 in the H38 temper would provide for the highest tensile strength, but to maintain the functional flexibility of the qajaq frame, I would specify a temper with less tensile strength: H32. Unlike the 2, 6, and 7 series aluminum alloys, 5 series aluminum cannot be heat treated to improve strength. [18] For the intended purposes of this build, that is not of concern. Therefore, through this study of aluminum material properties, the most appropriate aluminum alloy is 5056-H32 given its high corrosion resistance and relative flexibility.

CHEMICAL COMPOSITION LIMITS FOR ALUMINUM ALLOYS

Composition in percent by weight according to The Aluminum Association. The values indicate maximum limits unless shown as a range or a minimum.

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	OTHERS	OTHERS	Al
EACH	TOTAL	MIN.									
1070	0.2	0.25	0.04	0.03	0.03	—	0.04	0.03	0.03	—	99.7
1060	0.25	0.35	0.05	0.03	0.03	—	0.05	0.03	0.03	—	99.6
1050	0.25	0.4	0.05	0.05	0.05	—	0.05	0.03	0.03	—	99.5
1350	0.1	0.4	0.05	0.01	—	0.01	0.05	—	0.03	0.1	99.5
1145	0.55 Si + Fe		0.05	0.05	0.05	—	0.05	0.03	0.03	—	99.45
1100	0.95 Si + Fe		0.05-0.20	0.05	—	—	0.1	—	0.05	0.15	99
2024	0.5	0.5	3.8-4.9	0.30-0.9	1.2-1.8	0.1	0.25	0.15	0.05	0.15	Rem.
3003	0.6	0.7	0.05-0.20	1.0-1.5	—	—	0.1	—	0.05	0.15	Rem.
3004	0.3	0.7	0.25	1.0-1.5	0.8-1.3	—	0.25	—	0.05	0.15	Rem.
3005	0.6	0.7	0.3	1.0-1.5	0.20-0.6	0.1	0.25	0.1	0.05	0.15	Rem.
3104	0.6	0.8	0.05-0.25	0.8-1.4	0.8-1.3	—	0.25	0.1	0.05	0.15	Rem.
4004	9.0-10.5	0.8	0.25	0.1	1.0-2.0	—	0.2	—	0.05	0.15	Rem.
4104	9.0-10.5	0.8	0.25	0.1	1.0-2.0	—	0.2	—	0.05	0.15	Rem.
4043	4.5-6.0	0.8	0.3	0.05	0.05	—	0.1	0.2	0.05	0.15	Rem.
4045	9.0-11.0	0.8	0.3	0.05	0.05	—	0.1	0.2	0.05	0.15	Rem.
5005	0.3	0.7	0.2	0.2	0.50-1.1	0.1	0.25	—	0.05	0.15	Rem.
5050	0.4	0.7	0.2	0.1	1.1-1.8	0.1	0.25	—	0.05	0.15	Rem.
5052	0.25	0.4	0.1	0.1	2.2-2.8	0.15-0.35	0.1	—	0.05	0.15	Rem.
5252	0.08	0.1	0.1	0.1	2.2-2.8	—	0.05	—	0.03	0.1	Rem.
5056	0.3	0.4	0.1	0.05-0.20	4.5-5.6	0.05-0.20	0.1	—	0.05	0.15	Rem.
5657	0.08	0.1	0.1	0.03	0.6-1.0	—	0.05	—	0.02	0.05	Rem.
5182	0.2	0.35	0.15	0.20-0.50	4.0-5.0	0.1	0.25	0.1	0.05	0.15	Rem.
6061	0.40-0.8	0.7	0.15-0.40	0.15	0.8-1.2	0.04-0.35	0.25	0.15	0.05	0.15	Rem.
7075	0.4	0.5	1.2-2.0	0.3	2.1-2.9	0.18-0.28	5.1-6.1	0.2	0.05	0.15	Rem.

Rem.=Remainder

Figure 2.04

TYPICAL MECHANICAL PROPERTIES

The following typical properties are not guaranteed since in most cases they are averages for various sizes and methods of manufacture and may not be exactly representative of any particular product or size. The data is intended for comparing alloys and tempers and should not be used for design purposes.

		Tensile Strength	Yield Strength	Elongation (%) for the following gauge ranges:		Tensile Strength	Yield Strength	Elongation (%) for the following gauge ranges:	
Alloy	Temper	(ksi)	(ksi)	0.010-0.050″	0.051-.125″	(MPa)	(MPa)	0.25-1.25mm	1.26-3.0mm
1100	O	13	5	30	32	89.6	34.5	30	6
	H12	16	15	4	12	110.3	103.4	4	12
	H14	18	17	3	10	124.1	117.2	3	10
	H16	21	20	2	8	144.8	137.9	2	8
	H18	24	22	2	6	165.5	151.7	2	6
1350	O	12	4	34	42	82.7	27.6	34	42
	H12	14	12	5	12	96.5	82.7	5	12
	H14	16	14	3	9	110.3	96.5	3	9
	H16	18	16	3	8	124.1	110.3	3	8
	H19	27	24	2	6	186.2	165.5	2	6
2024	O	27	11	18	20	186.2	75.8	18	20
	T3	70	50	16	18	482.6	344.7	16	18
	T4	68	47	20	19	468.8	324.1	20	19
3003	O	16	6	30	33	110.3	41.4	30	33
	H12	19	18	9	11	131	124.1	9	11
	H14	22	21	3	7	151.7	144.8	3	7
	H16	26	25	3	5	179.3	172.4	3	5
	H18	29	27	3	5	199.9	186.2	3	5
3004	O	26	10	19	23	179.3	68.9	19	23
	H32	31	25	6	15	213.7	172.4	6	15
	H34	35	29	5	10	241.3	199.9	5	10
	H36	38	33	5	8	262	227.5	5	8
	H38	41	36	4	6	282.7	248.2	4	6
3005	O	20	8	22	23	137.9	55.2	22	23
	H12	26	24	5	13	179.3	165.5	5	13
	H14	29	28	4	9	199.9	193.1	4	9
	H16	31	30	3	5	213.7	206.8	3	5
	H18	37	36	2	3	255.1	248.2	2	3
5005	O	18	6	22	25	124.1	41.4	22	25
	H12	20	19	5	9	137.9	131	5	9
	H14	23	22	4	7	158.6	151.7	4	7
	H16	26	25	3	5	179.3	172.4	3	5
	H18	29	28	2	2	199.9	193.1	2	2
	H32	20	17	8	9	137.9	117.2	8	9
	H34	23	20	6	8	158.6	137.9	6	8
	H36	26	24	5	6	179.3	165.5	5	6
	H38	29	27	3	4	199.9	186.2	3	4
5050	O	21	8	20	25	144.8	55.2	20	25
	H32	25	21	9	13	172.4	144.8	9	13
	H34	28	24	5	10	193.1	165.5	5	10
	H36	30	26	4	7	206.8	179.3	4	7
	H38	32	29	2	4	220.6	199.9	2	4
5052	O	28	13	20	21	193.1	89.6	20	21
	H32	33	28	7	10	227.5	193.1	7	10
	H34	38	31	6	8	262	213.7	6	8
	H36	40	35	4	5	275.8	241.3	4	5
	H38	42	37	3	4	289.6	255.1	3	4
5056	O	42	22	23	24	289.6	151.7	23	24
	H38	60	50	6	13	413.7	344.7	6	13
5182	O	40	21	21	25	275.8	144.8	21	25
	H32	41	22	20	21	282.7	151.7	20	21
	H34	48	37	11	14	330.9	255.1	11	14
	H36	51	42	9	11	351.6	289.6	9	11
	H38	54	47	6	7	372.3	324.1	6	7
6061	O	18	8	25	26	124.1	55.2	25	26
	T4	35	21	22	24	241.3	144.8	22	24
	T6	45	40	12	17	310.3	275.8	12	17
7075	O	33	15	16	18	227.5	103.4	16	18
	T6	83	73	11	12	572.3	503.3	11	12

Figure 2.05

Figure 2.04

Data Sheet. United Aluminums chemical composition limits for aluminum alloys in percent by weight according to The Aluminum Association. The values indicate maximum limits unless shown as a range or a minimum.

Figure 2.05

Data Sheet. United Aluminums typical mechanical properties matrix intended for comparing alloys and tempers and should not be used for design purposes.

Figure 2.06

Graphs of kayak stability. Nick Schade of Guillemot Kayaks graphed stability curves based on different kayak hull shapes. These charts are to produce an unbiased performance reaction of the boat itself, rather than relying on the subjective opinion of others.

It is one thing to say "let's make a kayak frame from aluminum," and then there is doing it. Looking back at the comparative kayak categories, ease of fabrication is definitely of importance. On the shoulders of George Dyson's aluminum Baidarkas, I designed a sort of Vierendeel truss qajaq; the evolution of the wood qajaq using large tubular members as the gunwales, and aluminum sections cut from sheet stock as the cross members and ribs. Instead of having dimensionally larger and heavier wood members, the aluminum sections as hollow cylindrical tubes require less material to achieve a similar structural integrity; and so, forming a lighter kayak. Another factor that informed the decision to forgo wood in favour of aluminum is the amount of time saved in dressing the rough lumber, and designing within the standards of mill run lengths for aluminum tubes. I can order parts that are ready for assembly.

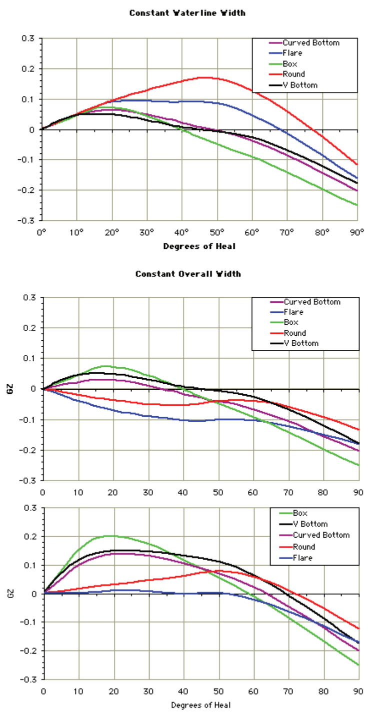


Figure 2.06

The characteristics of a traditional qajaq lend itself well to recreational paddling, so the form need not change, just the tippy-ness. And to aid in stability, I used mathematics to design the hull at the midpoint.[19] As opposed to "eyeballing it" as in the wood qajaq, I was able to establish that a cylindrical hull is a good average of primary stability and secondary stability. The cylindrical shape provides the delicate balance between primary and secondary stability that gives you the most stable kayak.

With the ideal aluminum alloy selected and a finalized design, I continued by requesting estimates for tubes, 16' long, ¾" exterior diameter, as thin of a wall thickness as possible. Initial costs of the less common 5056-H32 tubes with the thinnest wall thickness started at over $800. These estimated all accounted for shorter 12' lengths rather than the 16' lengths I needed. At this point, I had to seriously consider what is most important in the design of this skin-on-frame kayak. It has become apparent that there is the ideal, and then the pragmatic. On occasion, the two align although I'd say it's more likely they exist on two different spectrums. Given the function of a recreational kayak, the difference in tensile strength of the H38 temper and O temper is 95 MPa. This may be a significant amount structurally, but for the frame of a skin-on-frame kayak, the difference in tensile strength is negligible. The actual tectonics of the frame are more important to the resilience and flexibility. As for the corrosion resistance, aluminum alone has excellent corrosion resistance properties as an element.

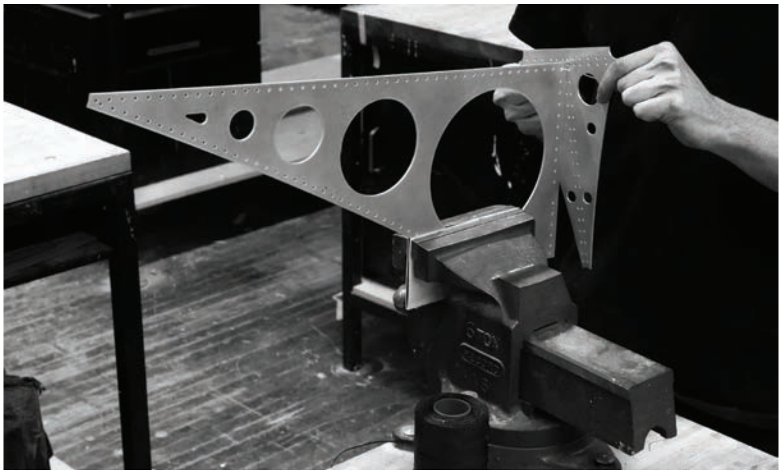


Figure 2.07

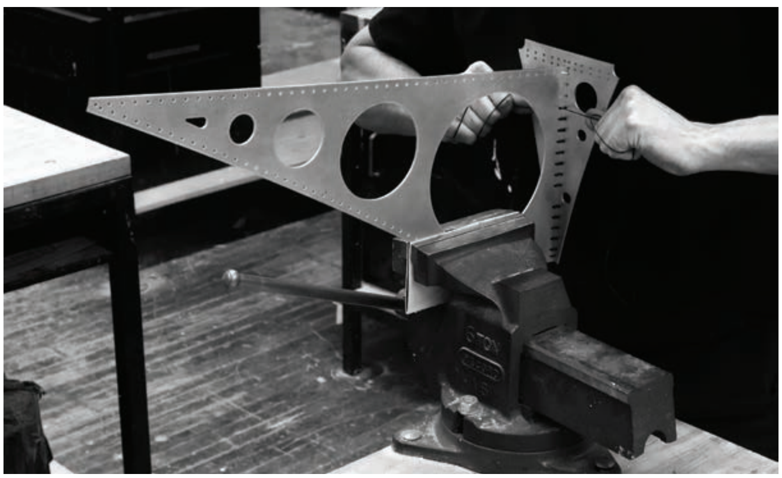


Figure 2.08

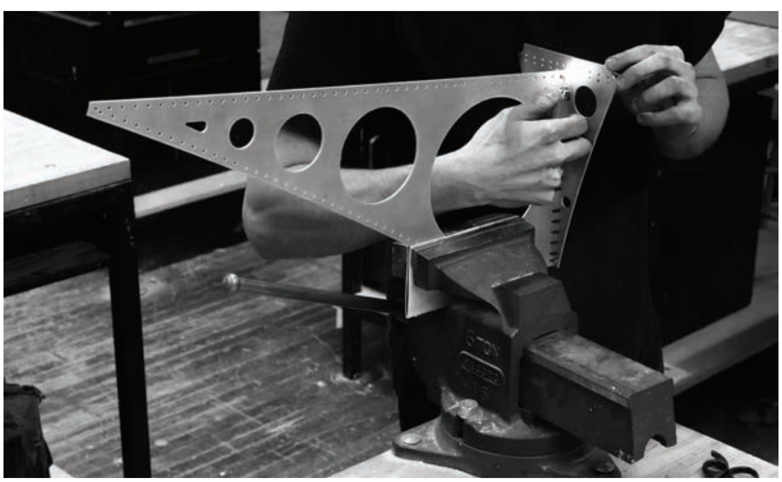


Figure 2.09

Figure 2.07
Stern and bow structure assembly. I align the back plate to the centre plate.

Figure 2.08
Stern and bow structure assembly. I saddle stitch the back plate using Tiger thread.

Figure 2.09
Stern and bow structure assembly. I then tie end knot and heat the frayed ends with a lighter and compress against knot.

Figure 2.10
Stern and bow structure assembly. I saddle stitch top plate to back and centre plate.

Figure 2.11
Stern and bow structure assembly. I continue stitching of the back plate.

Figure 2.12
Stern and bow structure assembly. Bow and stern are complete.

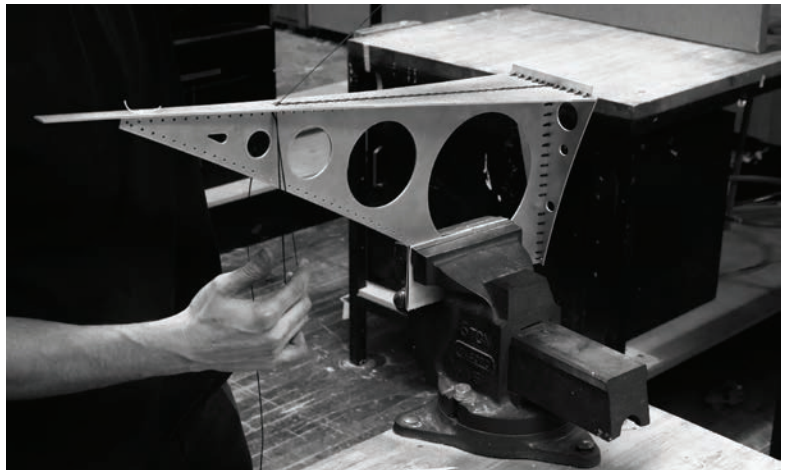


Figure 2.10

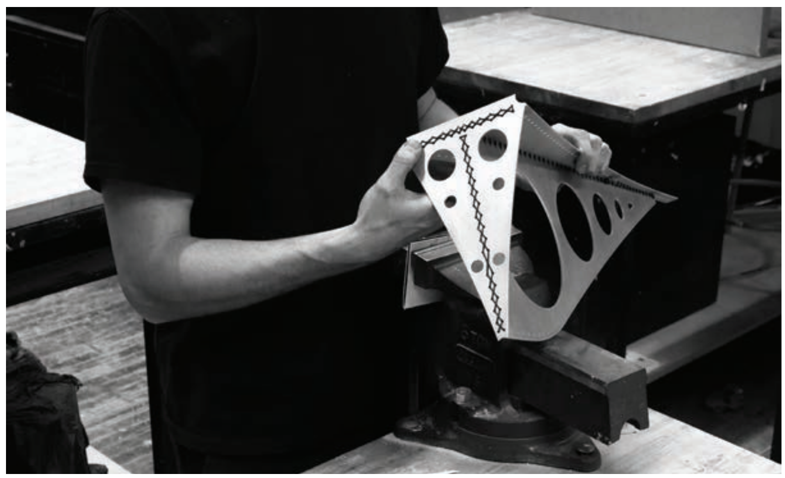


Figure 2.11

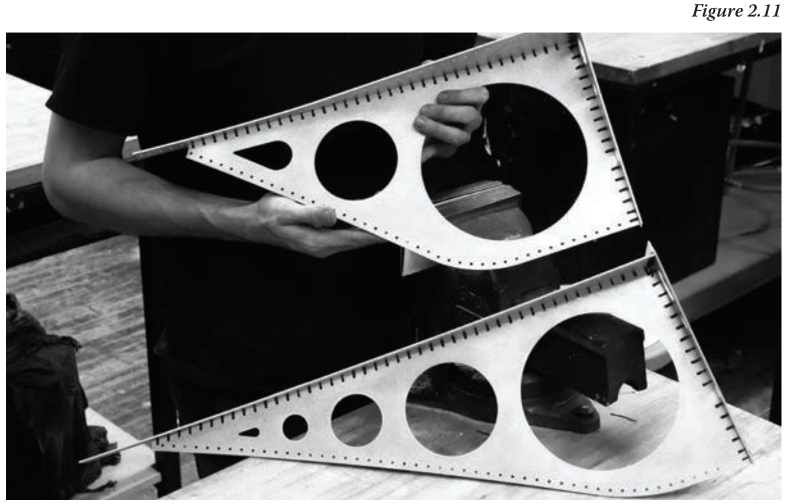


Figure 2.12

Figure 2.13
Kit of parts. Minus a tube roller, displayed are the parts and tools required to assemble a skin on frame kayak frame.

Pure aluminum will oxidize and form a chalky white layer of corrosion on its surface when exposed to contaminants.[20] That same corrosion layer also then acts as resistance to further corrosion (similar to the rot resistance properties of charring wood, shoshugi-ban), separating itself from other elements like iron in that regard. The deciding factor in the feasibility of building anything, as it is in the fabrication of this aluminum frame kayak, is cost. In architecture especially...

...money plays a paradoxical role in the creation... formless itself, money is a fundamental form giver. At all scales, and across the ages, architecture is a product of the financial environment in which it is conceived, for better or worse. Yet despite its ubiquity, money is often disregarded as a factor in conceptual design and is persistently avoided by architectural academia as a serious field of inquiry... In the contemporary world, in which economies are increasingly connected, architects must creatively harness the financial logics behind architecture in order to contribute meaningfully to the development of the built environment.[21]

Do the benefits of using the 5052-H32 aluminum alloy justify the additional cost compared to using the conventional and inexpensive 6061-O aluminum alloys? Any benefits, to the best of my knowledge, are indistinguishable to the recreational user, especially at three times the cost. Understanding the full capacity of aluminum is critical to understanding where modifications can be made. The knowledge gained from investigating the properties of aluminum is facilitated by contemporary technology and research, and allows for informed decisions. Unfortunately, these decisions are met with disappointment knowing that a material is not optimized due to financial restrictions.

It is not uncommon to have such a full depth of knowledge in a given material. This mastery in material knowledge suggests how a material can be exploited by a designer. Many "starchitects," as it were, famously started in other design disciplines where the in-depth knowledge of their respective trade began to influence their architectural designs. Mies Van der Rohe, whose father was a stonemason worked with stone, Le Corbusier had a fascination with sailing, Gaudí with ceramics, and Jean Prouvé had an in-depth knowledge in steel working.[22]

Comparatively, Jean Prouvé separates himself from the

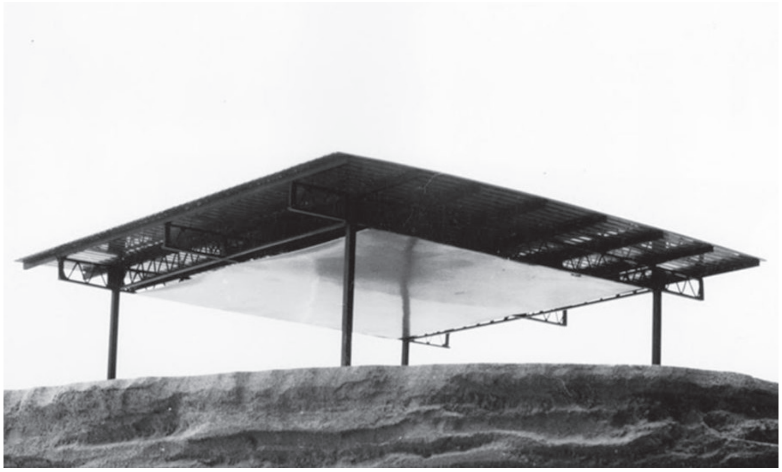


Figure 2.14

Figure 2.15

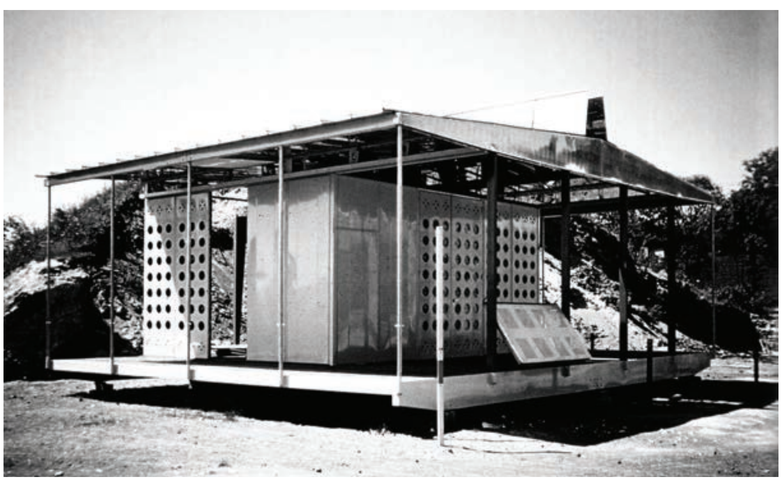


Figure 2.16

Figure 2.14 *Jean Prouvé Architecture by Eric Touchaleaume.* Habitat tropicale standard Cameroun.

Figure 2.15 *Jean Prouvé Architecture by Eric Touchaleaume.* Maison tropicale de Niamey au Niger

Figure 2.16 *Jean Prouvé Architecture by Eric Touchaleaume.* Maison tropicale de Niamey au Niger.

Figure 2.17 *Jean Prouvé sketch.* Gueridon rond table drawings.

Figure 2.18 *Jean Prouvé sketch.* Maison tropicale de Niamey au Niger.

three others with the fact that he is...

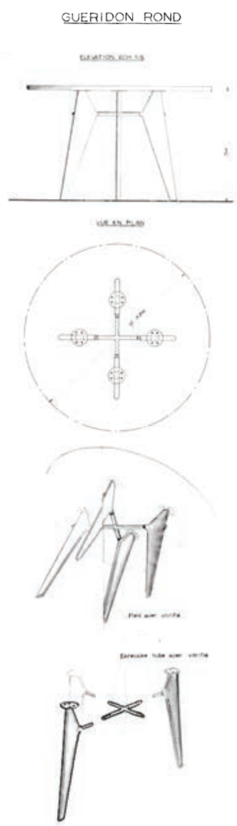


Figure 2.17

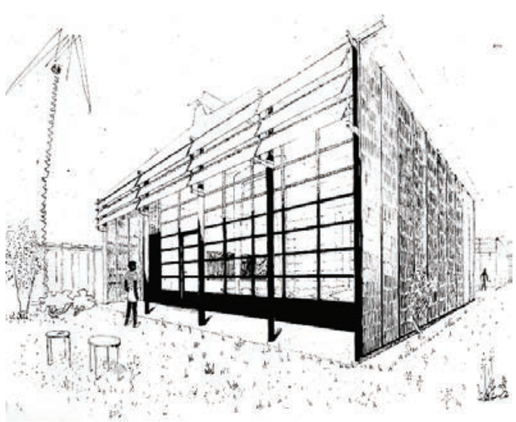


Figure 2.18

> *...widely acknowledged as one of the twentieth century's most important and influential designers whose wide-ranging oeuvre combined bold elegance with economy of means and strong social conscience. Working as a craftsman, designer, manufacturer, architect, teacher, and engineer, his career spanned more than sixty years, during which time he produced prefabricated houses, building components and façades, as well as furniture for the home, office and school. Prouvé trained as an artisan blacksmith and his intimate knowledge of metal remained the foundation of his work and career. Aware of the limitations of ornamental and wrought-iron work and keen to embrace the modern movement, he moved on to steel and aluminum, folding and arc-welding. He established the Atelier Jean Prouvé, where he began to produce light-weight metal furniture of his own design while also as collaborating with Le Corbusier and Charlotte Perriand. Furniture production became a core part of his business, although the potential for mass production inspired Prouvé to develop and patent industrial products using folded sheet metal for the construction of buildings. These included movable partitioning, metal doors and elevator cages. The onset of WWII and the age of austerity that followed marked a period of enforced experiment for Prouvé and in 1947 he moved his operations to Maxéville, just outside Nancy. With his own design studio, he could combine research, prototype development and production and at Maxéville he set about fulfilling his ambitious plan to alter the building process from a craft-based practice to that of a mechanized industry, producing not only houses, prefabricated huts, doors, windows, roof elements and façade panels but also a production line for furniture based on his own designs.*[23]

Noted in Prouvé's work, there is a delicate balance in material selection. The weight tipping the balance in one favorable direction is economic value. Within design, an appropriate material is one that satisfies not only the physical qualities that fulfills the needs of a design, but also one that meets other design criteria, including cost.

The resolution to this is selecting the common, everyday 6061-0 aluminum and the most pragmatic material for the tubular frame construction of the qajaq, I can progress the design of aluminum frame qajaq costing. During my initial investigations into the construction of this Vierendeel Truss kayak, I used a combination of nylon and acetate tubes for a

Figure 2.19

Figure 2.20

Figure 2.21

Figure 2.19
Kayak assembly. Starts with attaching the stern and bow assemblies to keel member.

Figure 2.20
Kayak assembly. Obligatory Randy the custodian break.

Figure 2.21
Kayak assembly. Saddle stitch.

Figure 2.22
Kayak assembly. Knot the stitch.

Figure 2.23
Kayak assembly. Heat the frayed ends of the thread and compress the knot.

Figure 2.24
Kayak assembly. Rinse and repeat with the stitching of the gunwale tubes.

Figure 2.22

Figure 2.23

Figure 2.24

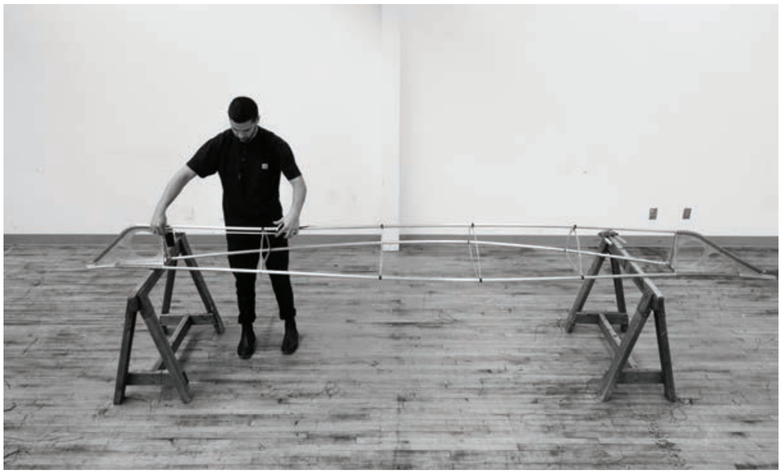


Figure 2.25

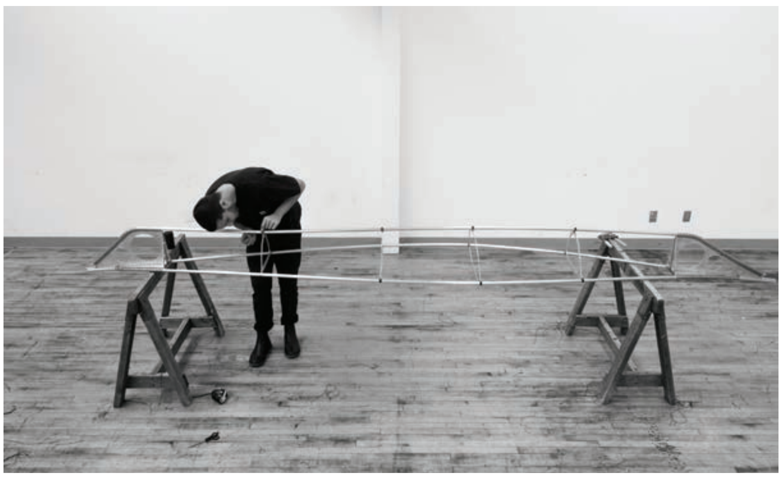


Figure 2.26

Figure 2.27

Figure 2.25
Kayak assembly. Once the end assemblies are attached, the sections can be inserted and stitched.

Figure 2.26
Kayak assembly. The sections then are measured from the stern to determine the final position.

Figure 2.27
Kayak assembly. Once the sections are in the proper locations, the remaining tubes can be installed.

Figure 2.28
Kayak assembly. Lashing the tubes and sections together.

Figure 2.29
Kayak assembly. Heating the frayed ends of the thread with a lighter and compress against the knot.

Figure 2.30
Kayak assembly. Clean-up.

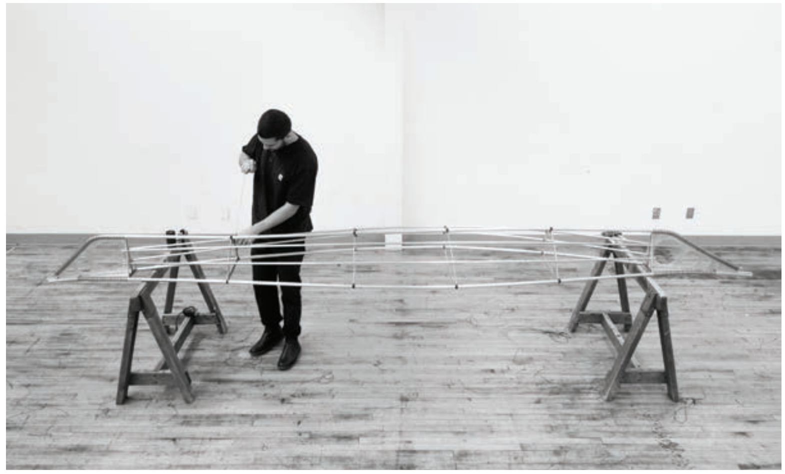
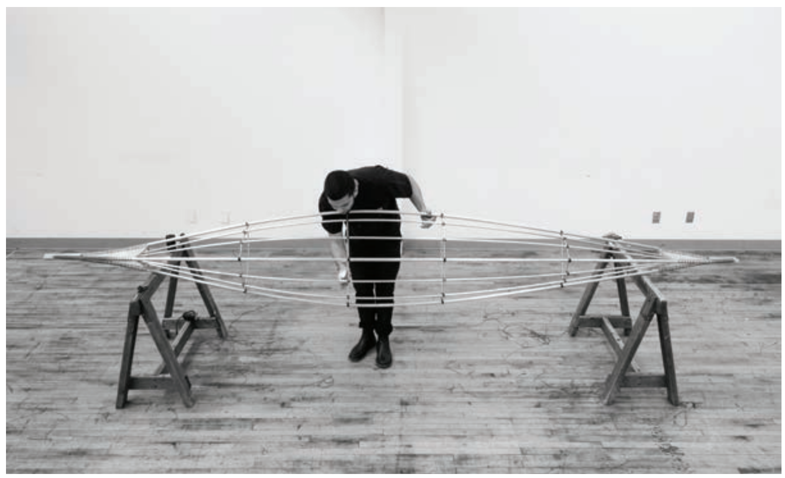


Figure 2.28



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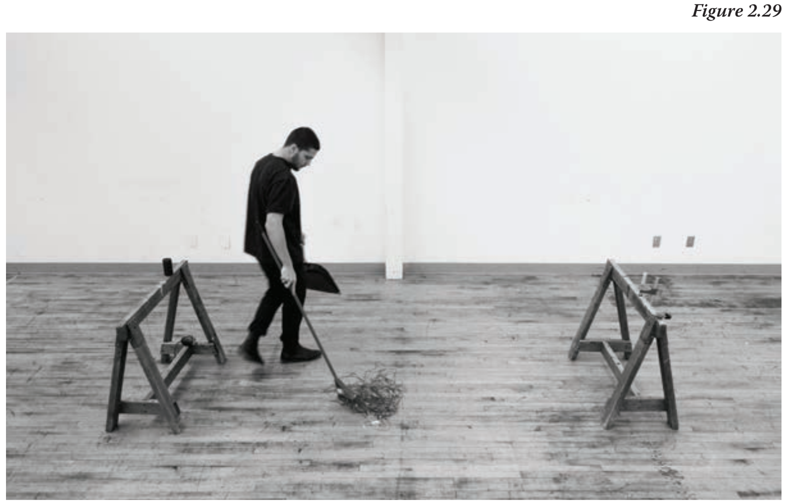

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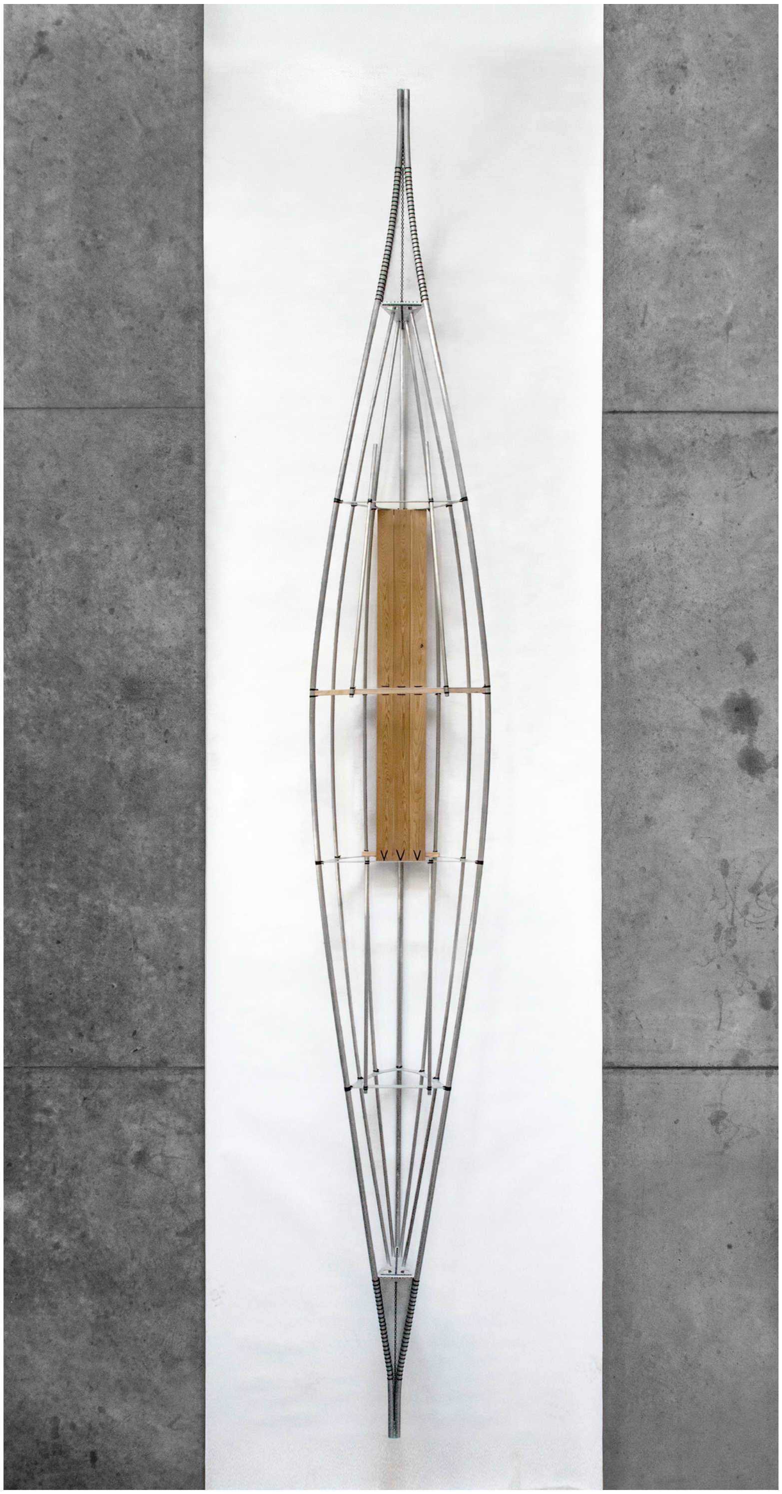

Figure 2.31

Figure 2.31
Aluminum frame kayak. Top view of skin-on-frame-kayak.

half-scale model (which are malleable yet rigid). The tubes are formed into shape by lashing them to the bow and stern assemblies. Due to restrictions of materials available in the GKWA and GTA I was unable to purchase aluminum tubes with 0.035" or even .049" wall thickness for the full-scale aluminum model. And so, my specified beautiful and delicate thin walled aluminum tubes became these chunky and robust members with a wall thickness of .065". The increased wall thickness proved nearly impossible to bend the tubes into place at either end using the forceful lashing technique I implemented previously on the plastic model. The solution was contouring the thicker walled tubes using a rolling tube bender. Luckily, the tubes were pliable enough to flex over the length of the kayak naturally.

A significant design detail was solving the connection between the sections and the tubes. This includes a rigid bow and stern assembly while maintaining that the fabric draws hydro-dynamically across the whole structure, free of large protrusions. I have some experience with leatherworking and used my knowledge of saddle stitching to devise a plan for fastening the parts together using Ritza Tiger thread - a waxed polyester thread. The ends are made of separate planar parts lashed together forming a three-dimensional framework. The lashing was an integral part of the traditional qajaq, and it was important to continue that fastening method in this and any new iteration. Cutouts were added to reduce weight and to ensure water can escape from either end.

I purchased discount knotted cedar boards from Home Depot for use as the decking. Again, urban beachcombing for clear boards. The total fabrication time of the frame is approximately 17 hours, which I spread over three days, Contrary to the four months it took to build a wood kayak while attending classes, this process was quick. There are a few details in the design of the aluminum qajaq that were overlooked; time consuming stitching as one example. Pressing my knees against a 3/16" aluminum section is another issue I clearly failed to address. In strategic locations, I added additional wood to the sections strictly to reduce pain, like wearing a bandage on the back of your heel in preparation to break-in new shoes. Although there was some time spent dressing wood in this iteration, it is a vast improvement on the fabrication time spent on the traditional qajaq. The overall weight of the aluminum frame is 17 pounds. The wood frame sits at approximately 40

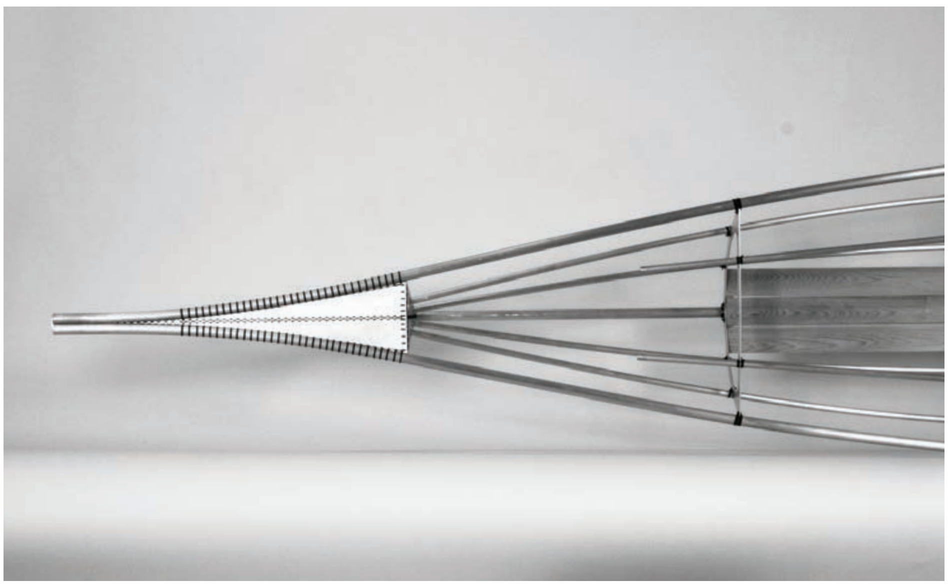

Figure 2.32
Aluminum frame kayak. Photo of the front end of the kayak.

Figure 2.33
Rails to section connection. Connection of the aluminum tubes to the aluminum sections.

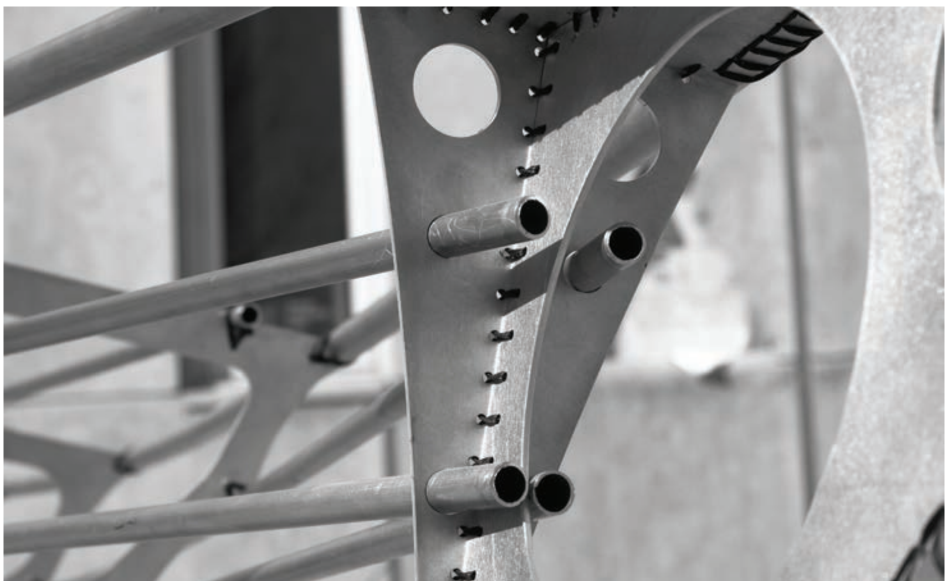

Figure 2.34
Joint connections. The connections of the smaller rails to the stern and bow do not need to be complicated. Since their purpose is to strictly allow the fabric to flow dynamically, there are no applied forces that would cause them to escape the holdings within the bow and stern assembly.

Figure 2.35
Joint connections. Connection of the aluminum tubes to the aluminum sections.

Figure 2.36

Figure 2.37

Figure 2.38

Figure 2.36

Joint connections. How the decking was to connect to the frame was an oversight. This wood support for th decking was the impromptu solution.

Figure 2.37

Joint connections. Another oversight being the knee brace. Rather, the lack of a substantial member that will not amputate my legs if rested upon.

Figure 2.38

Joint connections. Decking stitching.

pounds. As for cost, the aluminum qajaq frame is about $350 as opposed to the $200 wood frame. This includes the laser cutting of the aluminum sections. Final analysis of this iteration is as follows:

~~Durability~~

Without having tested this aluminum frame qajaq, compared to the durability of a plastic kayak it is safe to assume that it would not be as durable. Aluminum is not known for its material memory, and smashing into a rock or dropping it from heights may deform the tubes. Also, the stitching may start to wear once it loses its waxed coating where it meets the nylon skin.

✓Weight for ease of transportation

The weight, at 17 pounds is an outstanding improvement when compared to both its plastic, and wood frame counterparts.

~~Ease of fabrication and replication~~

The tube roller was definitely not ideal for ease of replication, and the amount of stitching was simply annoying. Meditative, yes, but maddening nonetheless.

✓Cost

$350 is an improvement to the plastic qajaq, yet still more expensive than the wood. If time spent fabricating had a cost value, the aluminum qajaq would be less expensive than the wood frame.

✓Proportionally fitted optimizing performance

This model can easily be adjusted for different frame sizes allowing for each user to customize a frame that fits them appropriately. Very similar to bicycles the cyclist uses a frame size appropriate to their body proportions.

✓Aesthetically pleasing

Is this aluminum frame qajaq pleasing to the eye? Compared to a plastic kayak, definitely so.

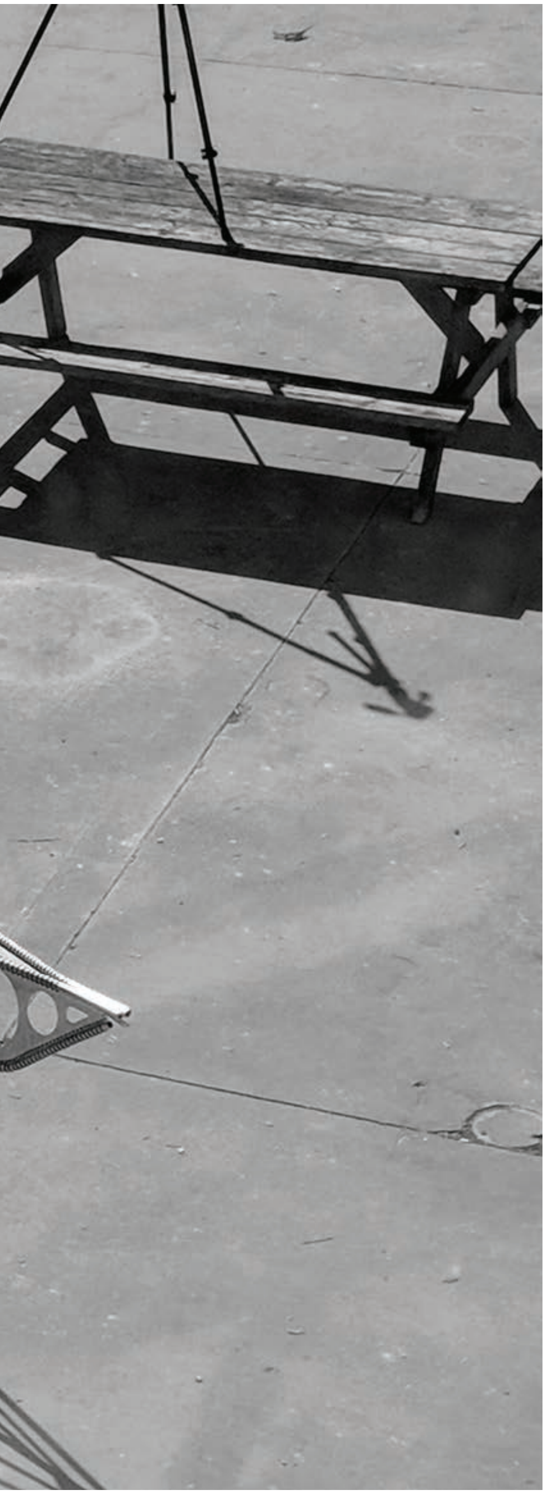

Figure 2.39
ACM. Fred Hunsberger took a photograph of me taking photographs.

Plastic

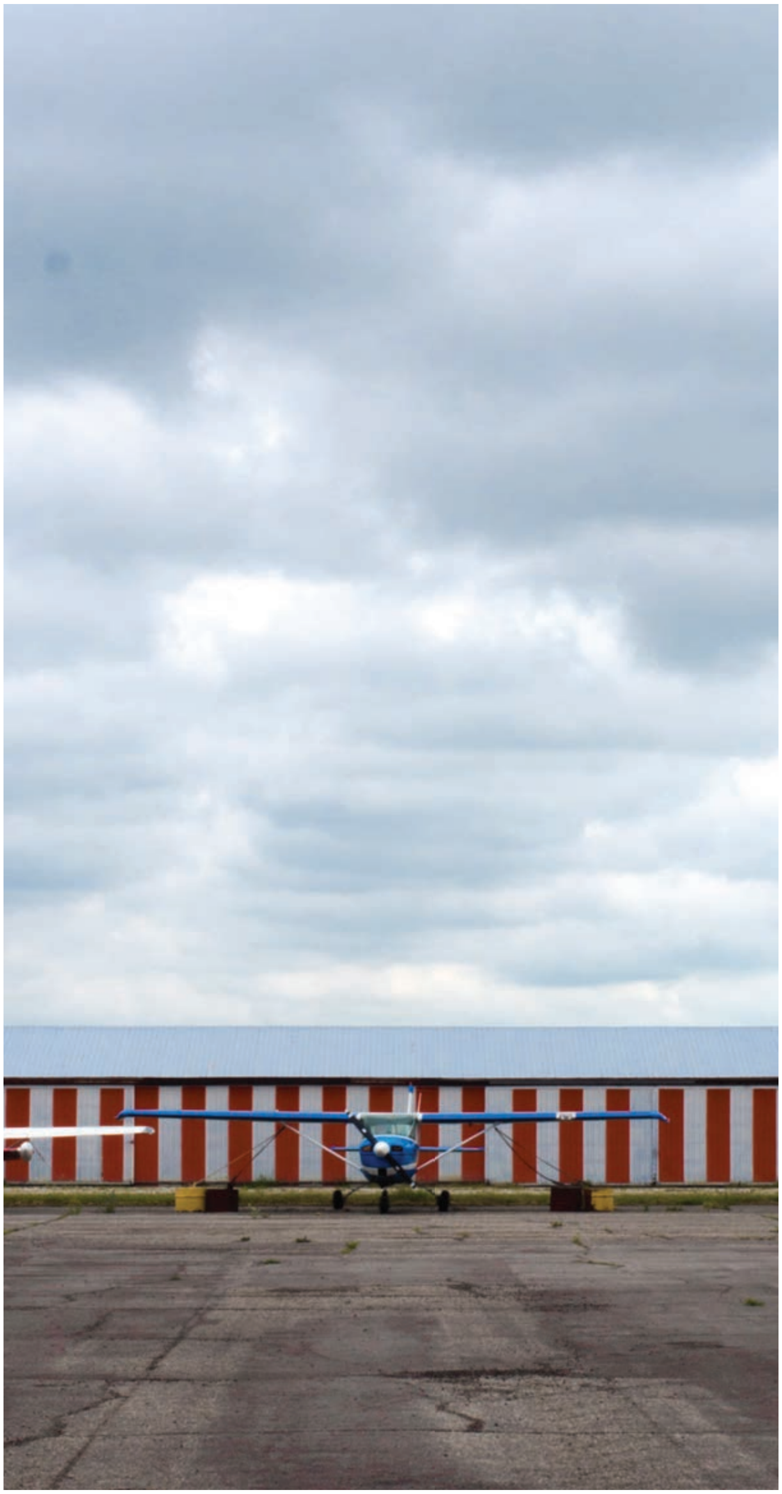

Figure 3.01
Brantford Airport. The precarious shed in the back is stored with hobbyist air crafts. Aircraft Spruce & Specialty Co. is just down the road.

Plastic

During my visit to Aircraft Spruce in Brantford, Ontario to purchase the small diameter aluminum tubes for the aluminum frame qajaq, I spoke with a fellow customer, Rob, or Bob. Quite possibly even George. It was a name that made me think, "ah, what a common name. I'll remember this." Well, I forgot his name but, I haven't forgotten our conversation. Keeping in mind that Aircraft Spruce is a hobby shop store located on the grounds of the Brantford Airport, most patrons are building one or two seat aircrafts, some full scale, and some model size.

George begins the discussion by inquiring why I need the tubing. I explain to him I was making an aluminum frame kayak. He quickly turns to me and asks, "wanna see something?" A part of me thinks, "beware, stranger danger!" but the logical part thinks, "I'm the one with the beard, buzzed head, and wearing a Harley Davidson t-shirt… I'm the danger, and the stranger." So, I oblige, hop into his early 2000's Dodge caravan and drive around the corner to a structure that is three huffs and a puff from falling over. He opens the sliding cedar door and there rest two small aircrafts – a one-seater sitting in disrepair he claims he crashed, and a new two-seater painted cherry red, and under construction. The newer of the two planes had an aluminum frame with a lightweight polymer skin. He lifts the polycarbonate cockpit shield and suggested I pop my head into the cockpit. The intersecting frame of aluminum tubes and extruded aluminum sections is a fascinating site. As I analyze the plane, he tells me more about his life, his kids, and battle with an infection, but for all intents and purposes, I am not listening. I am focused on the frame.

Returning to the school's fabrication lab with my tubes and a five-inch thick catalogue of Aircraft Spruce stock items in hand, I reconsider the structural make-up of the frame. It is not a perfect assembly. In addition to the aluminum tube-to-section connection, susceptible to slipping, and time consuming stitching of the bow and stern assembly, there are structural limitations to a Vierendeel Truss.

The Vierendeel transfers shear from the chords by bending moments

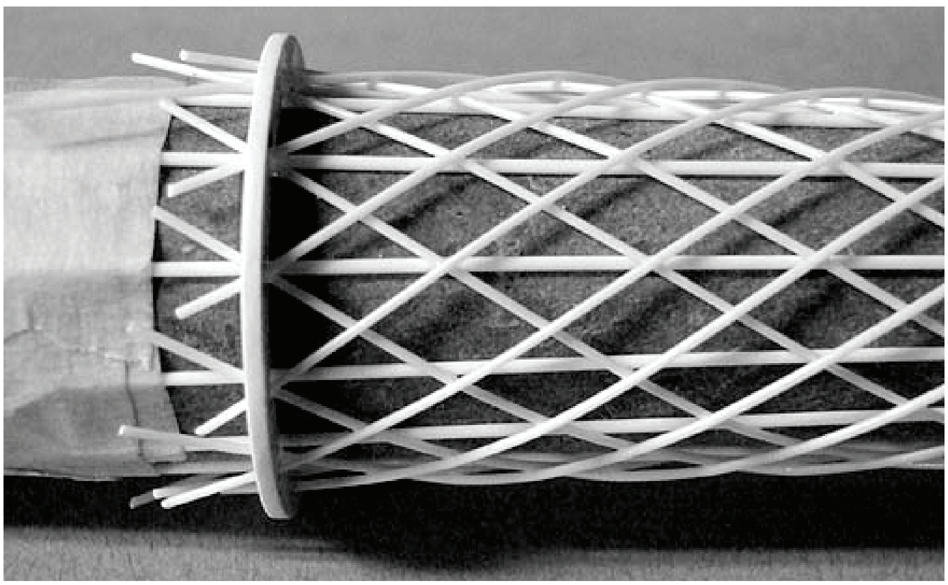

Figure 3.02
Geodesic Tower by Rob Chester. There are two rings of plastic drilled to accommodate for 12 uprights and a series of smaller holes, two at each upright on slight angles, to accept the winding members. One layer of the smaller rod spirals clockwise around the tube, while the outer layer spirals counter-clockwise. The correct name for this is an isogrid lattice. Commonly found for the design of stiffened composite pressure vessels.

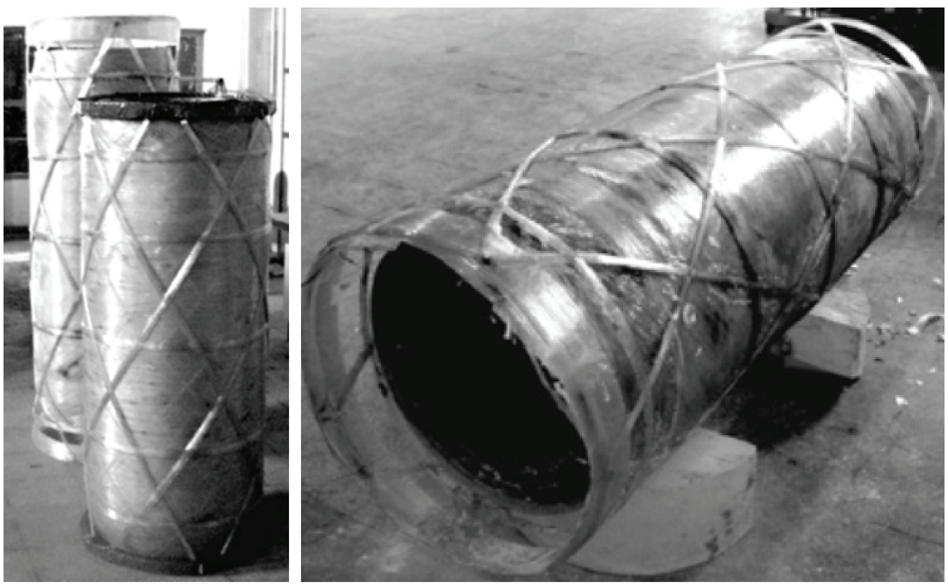

Figure 3.03

Pressure vessels. The correct name for Rob's design is an isogrid lattice. Commonly found for the design of stiffened composite pressure vessels. Photographed are three experimental stiffened composite pressure vessels.

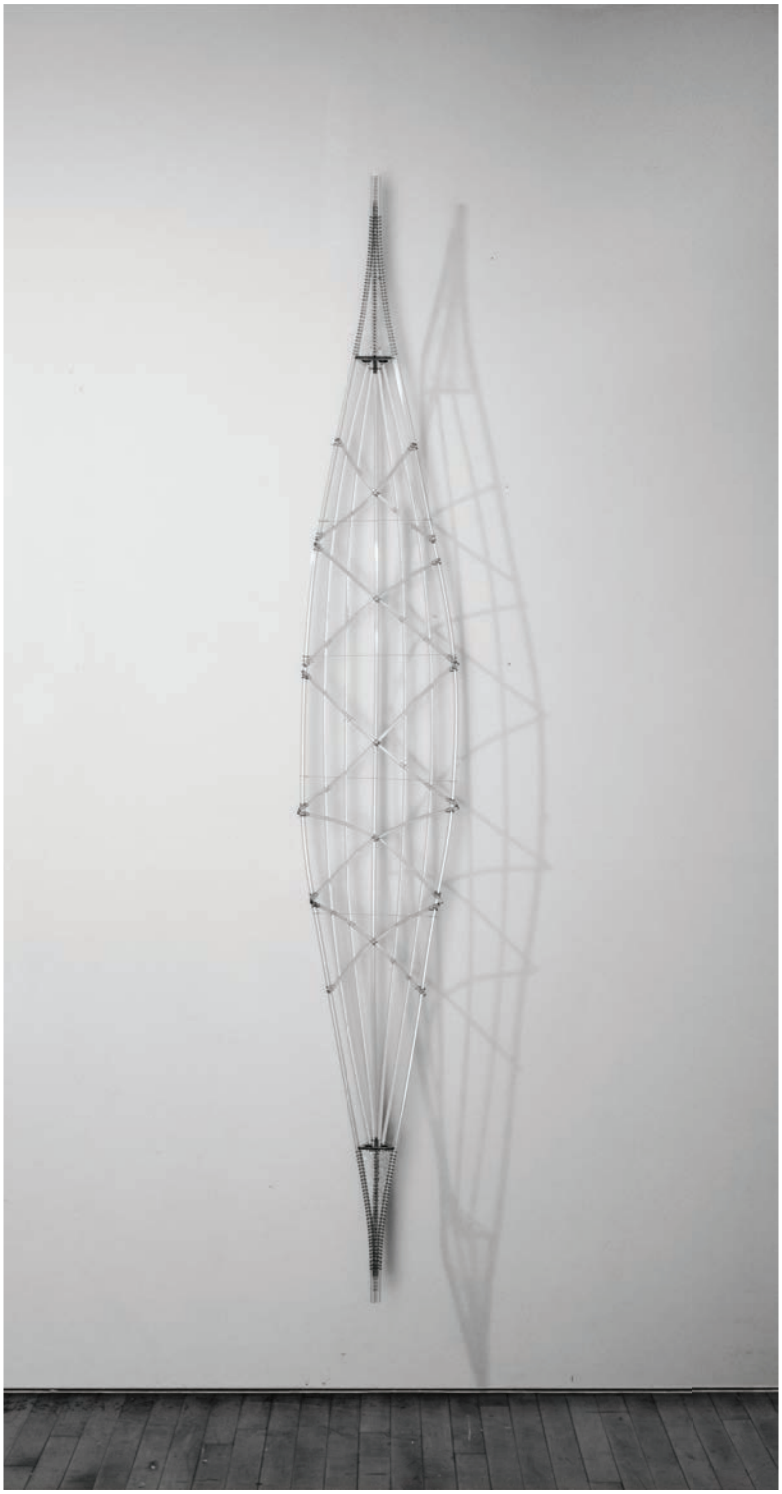

Figure 3.04
Isogrid kayak attempt 1.
First attempt in creating a non-cylindrical isogrid lattice kayak using bent rods lashed to tubes and rods. This specific model did not account for a cockpit.

at the joints and finally by bending moments in the vertical webs. As a result, all members are combined stress members in which axial, shear, and bending stresses exist.[24]

Force applied to one joint is translated amongst the others equally. In laymen terms, the frame has a tendency to shift and bend. Which makes a diagrid space frame an intriguing and promising fix for the racking on the aluminum qajaq design. I would need to make a tapered space frame that holds my body in its open internal area.

Searching the Internet for images of lattice or diagrid space frames, I came across a photograph of a geodesic cylinder fabricated from plastic rods. The construction is similar to what I imagined a diagrid lattice kayak would resemble. In a kayak, the rods would either need to stop short or bend to form the top of the deck, and due to the length of the kayak, there would need to be a coupling connection extending and connecting the rods. Even with my reservations, I modeled this idea at half scale. I was not fully aware of the resistance polycarbonate rods would provide when trying to be bent. So much so, that after lashing the three rods together with much difficulty, the shape of the kayak was unpleasantly deformed.

Perhaps, if I used shorter pieces and connected them at the centre, it would be an easier method of construction. Then the design of the kayak would rely on unique connectors, rather than the members. Unless designed properly, connectors sitting proud of the connecting members creating bumps in the skin. If the kayak was a simplified cylindrical shape, time spent designing one connection and fabricating that one detail in bulk to offset the time spent on one object makes sense. This is the case of Renzo Piano's Sulphur extraction facility where The Renzo Piano Building Workshop designed modular panels to form a geodesic cylinder that could be easily disassembled and reassembled as the extraction progresses.

A more elegant and relevant example of detailed connection design is the IBM pavilion designed by the same architect. The pavilion was to be easily assembled and disassembled economically. There, attention and time were invested on the connection details between the extruded polycarbonate panels and the wood members. These details were duplicated throughout.

In 1983, IBM (International Business Machines Corporation), a

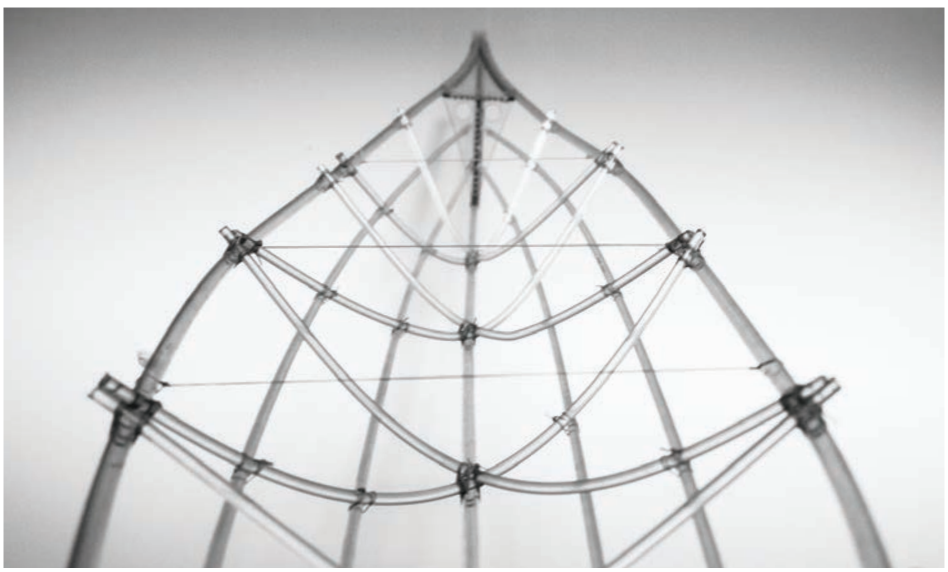

Figure 3.05
Deformity. The inconsistency in the bent rod's elasticity caused undesirable deformation of the form.

Figure 3.06

Connections. The kayak was kept from expanding using thread that was lashed to either gunwale at the midpoint between each rod. The rods were crudely lashed to the rails.

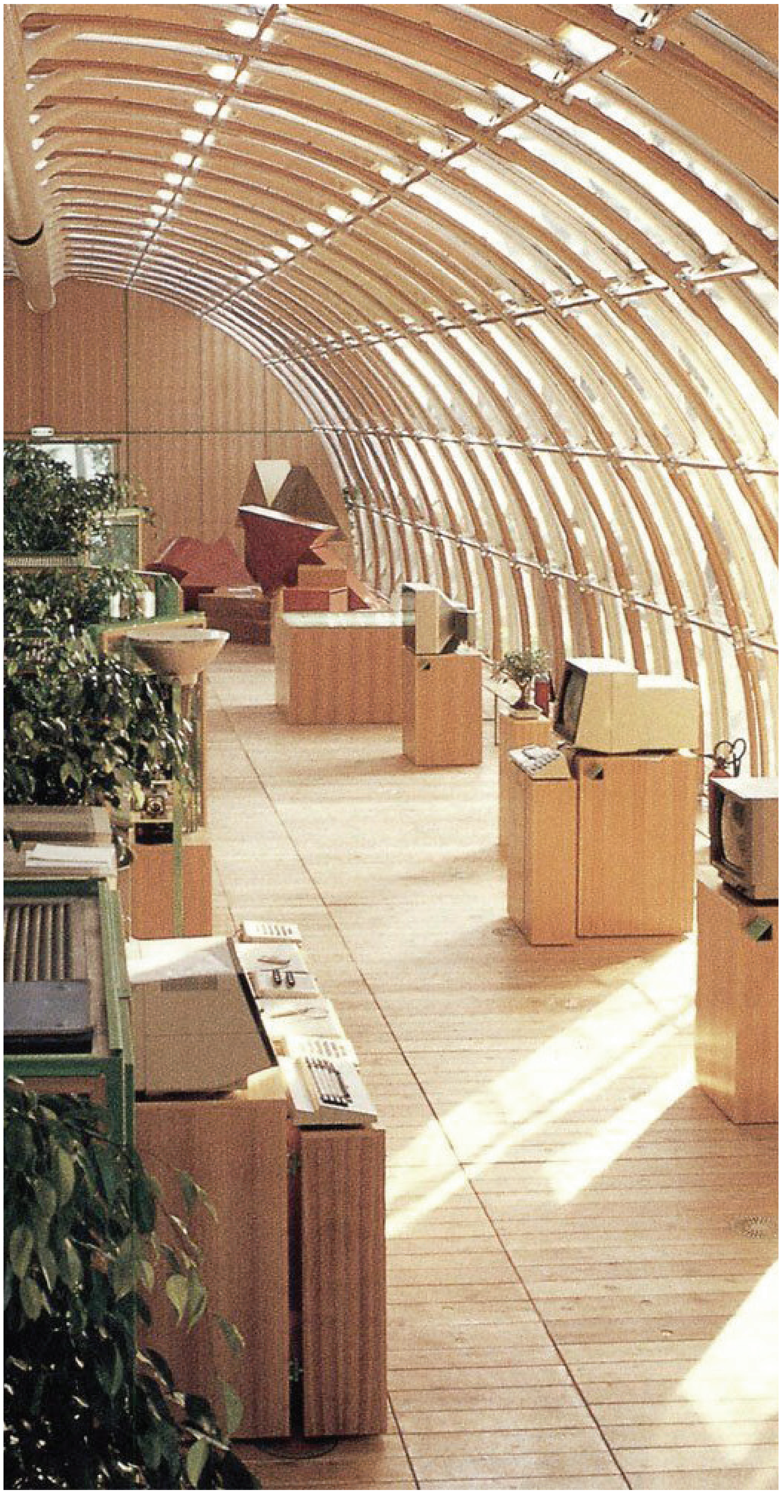

Figure 3.07

Figure 3.07
IBM Traveling Pavilion. 1983 - 1986, Paris, France. "In 1983, IBM devised a traveling exhibition to promote advances in computer technology for telecommunications. Reinforcing their message that workstations could be virtually located anywhere, this temporary structure was designed to be assembled, exhibited for a month, and then dismantled at each of its 20 European destinations..."

Figure 3.08
Connection sketch by Renzo Piano. Rough and final drawings of the joinery detail which is crucial to the design of the IBM Traveling Pavilion.

Figure 3.09
IBM Traveling Pavilion. Cross Section.

Figure 3.10
IBM Traveling Pavilion. Elevation of four assembled bays.

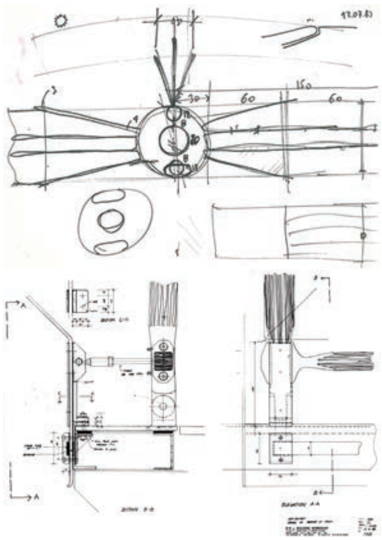

Figure 3.08

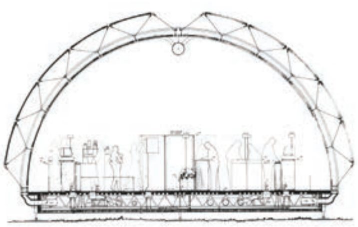

Figure 3.09

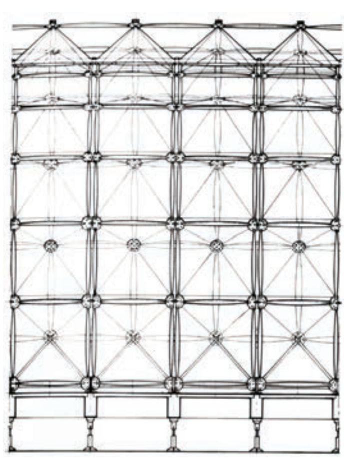

Figure 3.10

leading company in the computer industry, decided to promote the knowledge of technology, especially among young people, by creating a travelling exhibit that would bet set up, for one month at a time, in the parks of twenty different European cities. The building, 48 metres long, 12 metres wide and 7 metres high, was comprised of an entirely disassemble-able transparent tunnel, equipped with the various support systems for the computerized instrumentation that would be put on display. Each time the exhibition was moved, a specific project had to be developed in order to allow it to be inserted within the new context, while the functionality of the building itself only required a connection to a main electrical power source. The arch elements, being the modular structure of the building itself, were assembled upon an appropriately outfitted and raised platform that housed all of the necessary systems. The 34 arches, each with three hinges, were comprised of 68 semi-arches. These semi-arches were made up of three-dimensional beams in which a polycarbonate material served as both an external covering as well as the lattice structure between the inner and outer arches. Each individual arch was made up of 12 polycarbonate pyramids. The internal structure was mainly made out of three primary materials: wood, which was employed in the laminated beechwood uprights, cast aluminum, which was used for the joints, and transparent polycarbonate, which was used to construct the thermoformed pyramids that served as the structural and roof cladding elements.[25]

Piano's attention to all aspects of design - including time, material and finances - is a model for design practice. The project's execution, using the advancements in glue laminated construction, and die-cast aluminum, in combination with plastic is breathtakingly innovative. Unfortunately, this method cannot apply easily for the frame of kayak: the taper of the hull makes each connection unique.

My search for precedents concluded with photos of British warplanes and airships. Two in particular caught my attention: The R-100 airship, and the Wellington Bomber. The airplane is a relevant precedent for a kayak; the non-cylindrical frame needs to be lightweight and aerodynamic. Barnes Wallis and Rex Pierson led the aircraft design team, Pierson working on the general layout of the aircraft and Wallis designing the internal structure. Before working on the Wellington Bomber, Wallis designed the R-100 Airship. The large craft was innovative in having a massive internal space without any intruding framework. He used his research and experience in

Figure 3.11
IBM Traveling Pavilion. View of the exterior of the structure showcasing the pyramidal three dimensional truss.

Figure 3.12
IBM Traveling Pavilion. Close-up view of the structure in York suggesting how the public felt with its un-intimidating and welcoming presence.

Figure 3.13
IBM Traveling Pavilion. View of junctions in the interior of the pavilion.

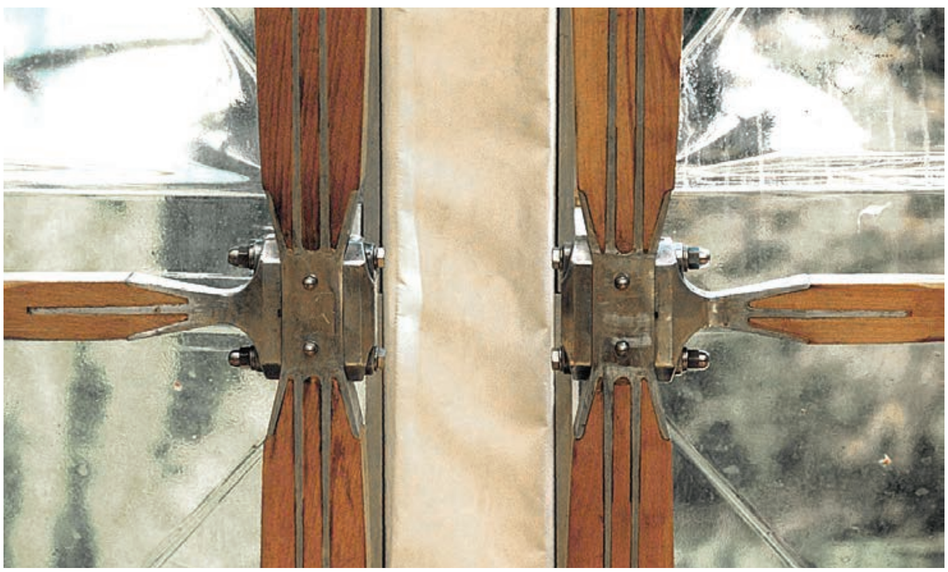

Figure 3.14
IBM Traveling Pavilion. The timber composed of thin beech laminations that are glued together to give structural uniformity. The timber connections are in cast aluminum.

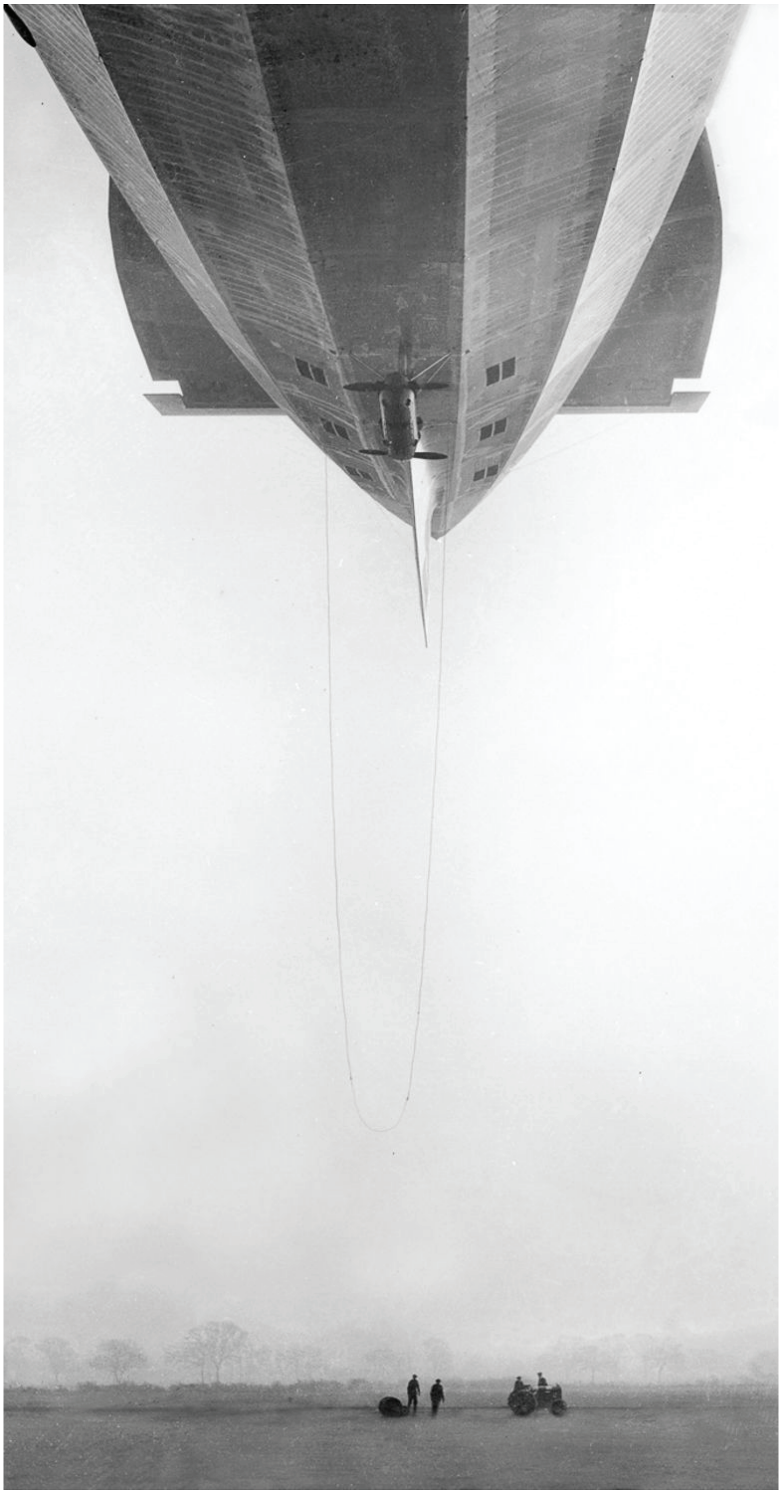

Figure 3.15

Figure 3.15
R-100 Airship.
The British aircraft leaves her mooring on her maiden voyage. Image via Fox Photos, Hulton Archive, Getty Images.

Figure 3.16
R-100 Airship.
Elevations and sections of the British airship showcasing the vastness and free interior volume that the structure produces.

Figure 3.16

the design and construction of the R-100 airship to inform the design of the Wellington. Wallis was interviewed saying the following regarding its design.

At that time (airplane) structure(s) consisted of a rectangular skeletal framework, the outer skin being doped fabric supported on a complicated and otherwise useless wooden framework shaped to produce a streamlined form, but with the disadvantage of adding considerably to the weight of the basic structure....With the knowledge of geodesics gained from the... R-100 in my mind, it occurred to me that I could not only abolish the wooden falsework but could at the same time enlarge the internal skeletal structure to full streamline dimensions, by forming its members as geodesics in the surface of both wings and fuselage, thus getting a much lighter, stiffer and stronger structure than ever before. [26]

In a geodesic framework, each of the aluminum members would have to be doubled, rotated 90 degrees, and intersected, increasing the cost and weight by a at least factor of two. This type of frame could be fabricated from a variety of materials although, given the additional members, an appropriate material would require a high strength to weight ratio. Aluminum is a viable option, but it may not be forgiving enough for this method of construction. Another possibility is a type of rigid plastic.

Albeit a technological achievement, plastic has a bad reputation regardless of it as a byproduct of human scientific resourcefulness. As a civilization, we often judge quality to make decisions. "Buy cheap, buy twice" and " buy once, cry once" are common sayings to justify quality purchases. Culturally, we've concluded it is always best to buy quality because it will last longer. Yet, we do not always follow this as scripture. There is something hypocritical about items made from plastic being associated with shoddiness or lacking quality. Biologically, plastic lasts forever; it does not decompose. Yet, it is associated with cheapness due to its abundance commonplace uses. And, since most plastics do not age gracefully with an attractive patina, we do not treat them with the same respect as clay, wood, leather, or other natural materials. Would I appreciate the complexities of small toy engineering if the toys were made of anything but plastic? Would I treat plastic items differently if they were anything but? Studies show that the landfills and oceans would benefit from a plastic-less world but as a society

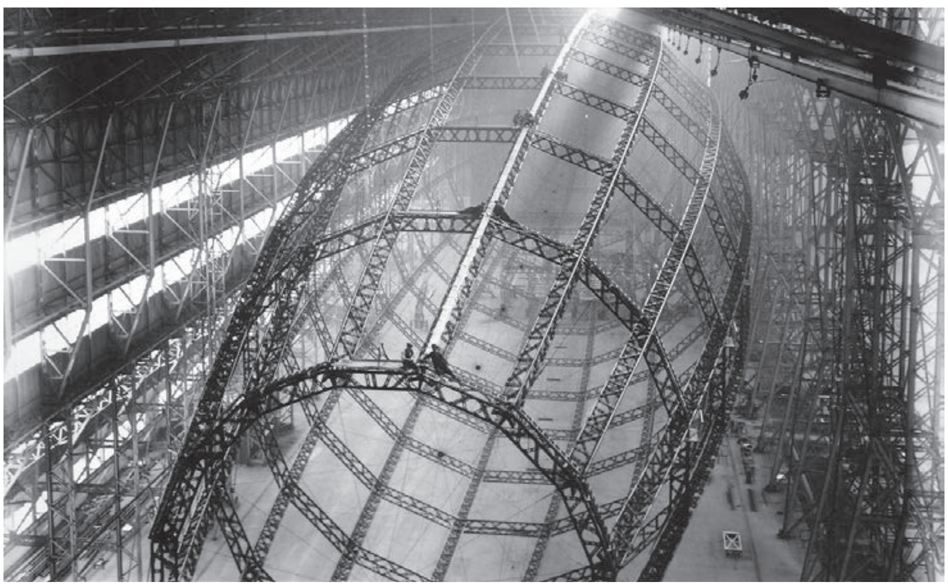

Figure 3.17
British Airship. The Barnes Wallis designed R-100 airship under construction in the Howden construction facility.

Figure 3.18
British Airship. The Barnes Wallis designed R-100 airship nears completion in its hangar in Yorkshire.

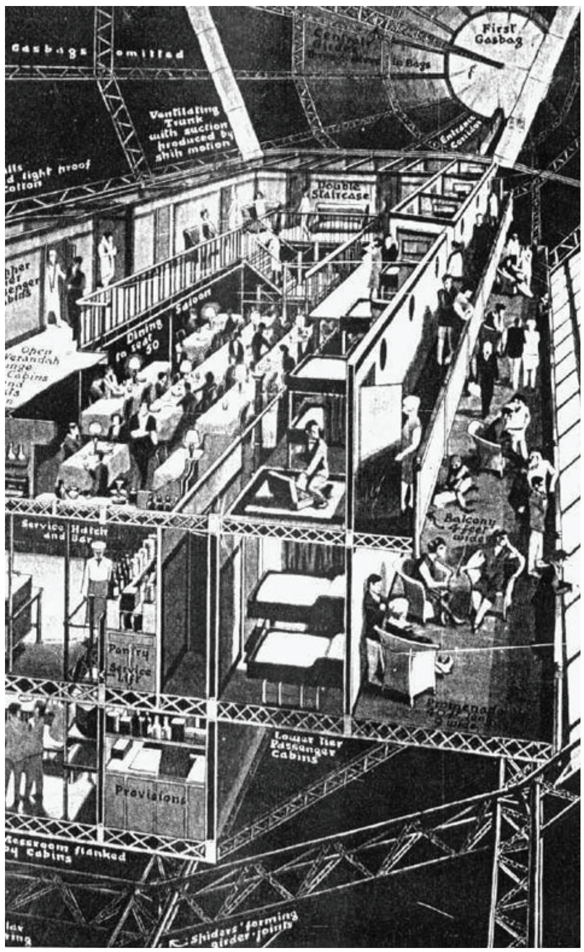

Figure 3.19
British Airship. A 1928 drawing by S W Clatworthy showing the accomodation aboard the R-100.

Figure 3.20
British Airship in Toronto. On August 1930 the British R-100 passed over the Canadian Bank of Commerce building in Toronto. At the time it was the tallest building in the British Empire. Image via City of Toronto Archives Fonds 16, Ser 71,# 7921.

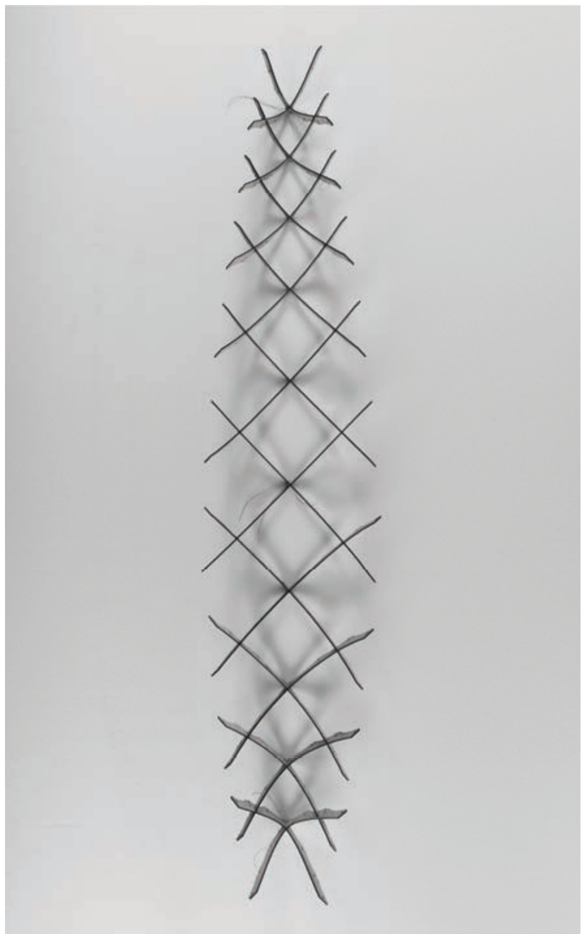

Figure 3.21
Attempt 2 of Isogrid Structure. A top view of the open top frame.

Figure 3.22
Attempt 2 of Isogrid Structure. Detail image of the intersection of the ribs with grooves cut for tubular rails.

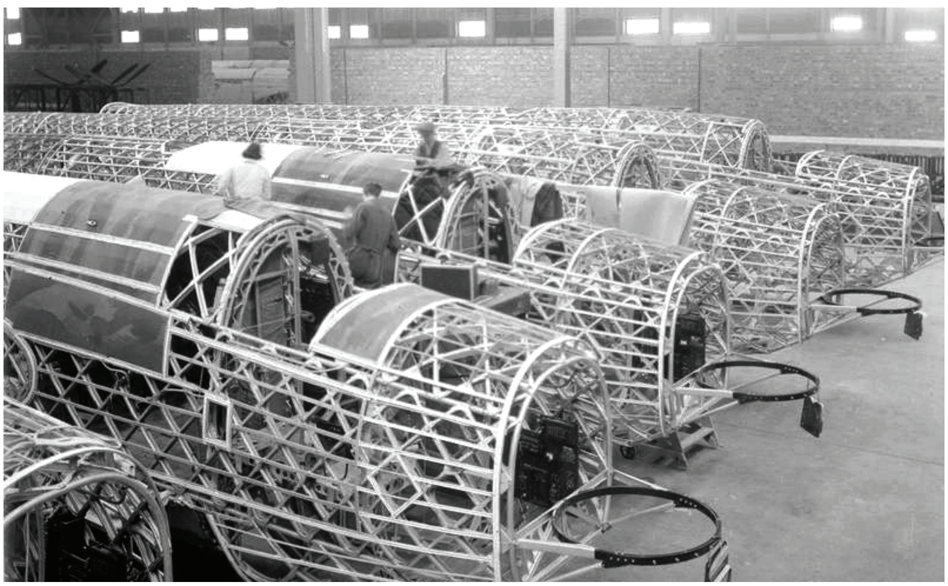

Figure 3.23
Wellington Bomber. Vickers Wellington bombers under construction.

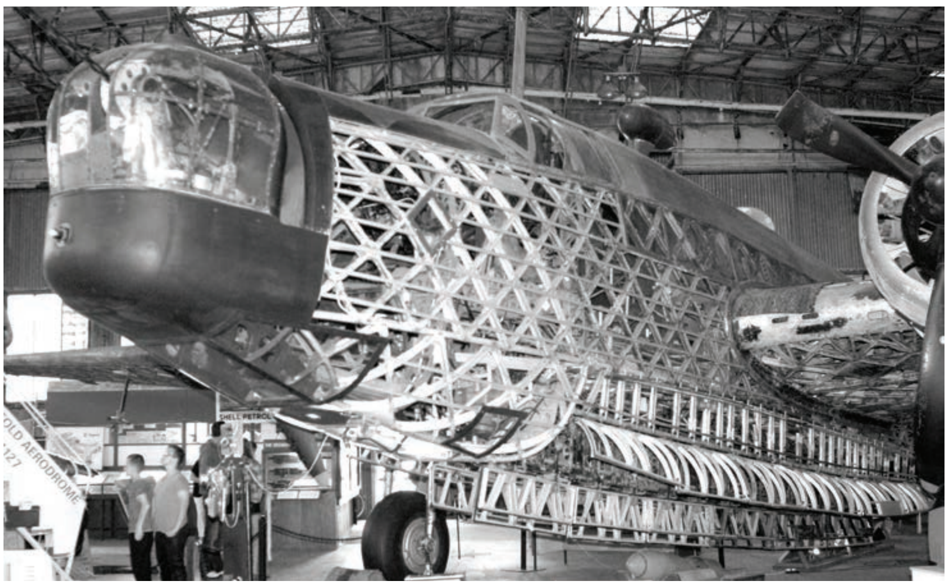

Figure 3.24
Wellington Bomber. The bomber today in the Brooklands Museum.

Figure 3.25
Wellington Bomber by Imperial War Museum. Crew members of a Vickers Wellington Mark III of the Sea Rescue Flight, based at LG 'X' (also known as LG 206/ Abu Sueir North), Egypt, at their stations by the beam gun positions of the aircraft during a search. The crewman on the left is using an Aldis signaling lamp to communicate with a ship.

Figure 3.26
Wellington Bomber by Imperial War Museum.
Assembly of Wellington Bomber. View of workers assembling Wellington from rear gunners platform.

Figure 3.27
Attempt 2 of Isogrid Structure.
The introduction of a closed isogrid slot rib intersections.

Figure 3.28
Attempt 2 of Isogrid Structure. Still working through how to connect rails to the intersecting sections. In this attempt, I've created small shelved for tubes or ribs to sit on. Although, lashing of the tubes simply drew the tubes towards the direction of tension. Not ideal.

Figure 3.29

Figure 3.30

Figure 3.31

Figure 3.29
Attempt 3 of Isogrid Structure. Mending plates stitching the seam of the ribs which facilitate intersections.

Figure 3.30
Attempt 3 of Isogrid Structure. . Photograph of the rails intersecting with the carcass. The depth of the rails could decrease in size, as long as the structural rigidity is maintained.

Figure 3.31
Attempt 3 of Isogrid Structure. . Photograph of the inside of the kayak showcasing the interesting frame.

with a global economy, we are reliant on plastic as much as oil, and international trade. Plastic has roots, like most inventions, in an accident, creating a polymer that allows for multiple variations through modifications. Scientifically, plastic is a compliant substance.

There are countless plastic polymers, each designed to perform optimally for its given function; Teflon for non-stick coatings is an example. Given the number of plastics, there must be a plastic best suited to an intersecting set of sections and rails forming the isogrid structure of a kayak, similar to that of a the Wellington Bomber.

The deliberation would consider factors such as cost-effectiveness, ultra-violet resistance, availability, machinability, and resilience. Based on research of plastic properties and characteristics, polycarbonate appears to be the appropriate choice. If you've ever tried to break a CD in half expecting it to shatter like glass, or bend like metal, you understand the properties of polycarbonate. Its tireless energy-storing resilience is considerably different than aluminum. Polycarbonate is not as strong or rigid, but I imagine it not need be so. The strength of the frame will derive from the assembly as a whole.

I spent time modeling in three dimensions; more than fifteen iterations of the intersecting, sloping, and complex isogrid qajaq attemping to find the optimal the thickness of sections, the spacing of the sections, and the rail connection to the rib carcass. At this point, most decisions were based on visual proportions, "feel" and cost. Each time I sent out cutfiles for an estimate, I would adjust the model until I received an acceptable price.

Of all the half-scale physical models I started, the aluminum half scale model of this isogrid qajaq was the most revealing. While building the traditional wood frame qajaq, I could tweak the design, making small adjustments based on what I physically saw. For me, three-dimensional modeling has its benefits: providing a means to generate the complex geometries of a tapered slot joint frame. Nevertheless, a glaring issue is scale. Without calculations aiding in section sizing for polycarbonate, it is extremely difficult to be critical of member sizing. The proportions of the kayak on screen differ from reality. I found myself subconsciously orbiting around the digital model and remaining fixed on views I admired, rather than facing the

Figure 3.32
Attempt 3 of Isogrid Structure. View of the stern assembly of aluminum frame half scale model of geodesic isogrid kayak.

Figure 3.33
Attempt 3 of Isogrid Structure. View of the underside of the aluminum frame half scale geodesic isogrid kayak assembly.

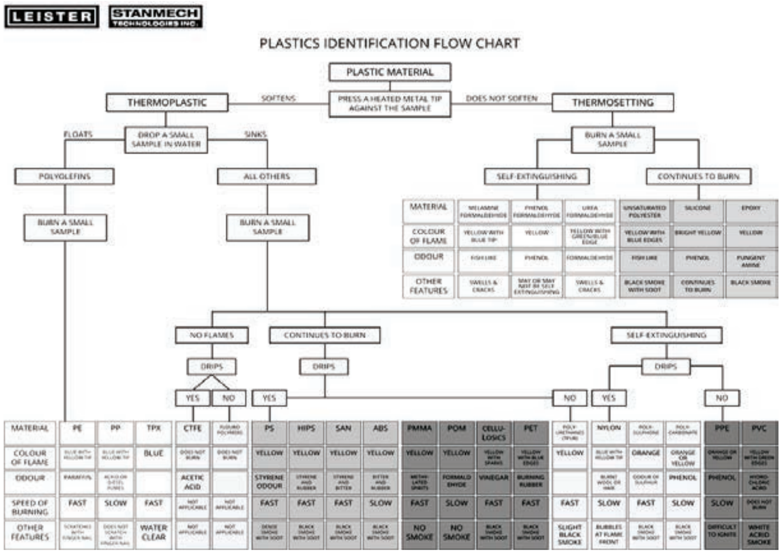

Figure 3.34

Polymer family and type	density (g/cm ^{3})	degree of crystallinity	glass transition temperature (° C)	crystal melting temperature (° C)	deflection temperature at 1.8 MPa (° C)	tensile strength (MPa)	elongation at break (%)	flexural modulus (GPa)	typical products and applications
Thermoplastics									
Carbon-chain									
High-density polyethylene (HDPE)	0.95-0.97	high	-120	137	--	20-30	10-1,000	1-1.5	milk bottles, wire and cable insulation, toys
Low-density polyethylene (LDPE)	0.92-0.93	moderate	-120	110	--	8-30	100-650	0.25-0.35	packaging film, grocery bags, agricultural mulch
Polypropylene (PP)	0.90-0.91	high	-20	176	--	30-40	100-600	1.2-1.7	bottles, food containers, toys
Polystyrene (PS)	1.0-1.1	nil	100	--	--	35-50	1-2	2.6-3.4	eating utensils, foamed food containers
Acrylonitrile-butadiene-styrene (ABS)	1.0-1.1	nil	90-120	--	--	15-55	30-100	0.9-3.0	appliance housings, helmets, pipe fittings
Polyvinyl chloride, unplasticized (PVC)	1.3-1.6	nil	85	--	--	40-50	2-80	2.1-3.4	pipe, conduit, home siding, window frames
Polymethyl methacrylate (PMMA)	1.2	nil	115	--	--	50-75	2-10	2.2-3.2	impact-resistant windows, skylights, canopies
Polytetrafluoroethylene (PTFE)	2.1-2.2	moderate-high	126	327	--	20-35	200-400	0.5	self-lubricated bearings, nonstick cookware
Heterochain									
Polyethylene terephthalate (PET)	1.3-1.4	moderate	69	265	--	50-75	50-300	2.4-3.1	transparent bottles, recording tape
Polycarbonate (PC)	1.2	low	145	230	--	65-75	110-120	2.3-2.4	compact discs, safety glasses, sporting goods
Polyacetal	1.4	moderate	-50	180	--	70	25-75	2.6-3.4	bearings, gears, shower heads, zippers
Polyetheretherketone (PEEK)	1.3	nil	185	--	--	70-105	30-150	3.9	machine, automotive, and aerospace parts
Polyphenylene sulfide (PPS)	1.35	moderate	88	288	--	50-90	1-10	3.8-4.5	machine parts, appliances, electrical equipment
Cellulose diacetate	1.3	low	120	230	--	15-65	6-70	1.5	photographic film
Polycaprolactam (nylon 6)	1.1-1.2	moderate	50	210-220	--	40-170	30-300	1.0-2.8	bearings, pulleys, gears
Thermosets*									
Heterochain									
Polyester (unsaturated)	1.3-2.3	nil	--	--	200	20-70	3	7-14	boat hulls, automobile panels
Epoxies	1.1-1.4	nil	--	--	110-250	35-140	4	14-30	laminated circuit boards, flooring, aircraft parts
Phenol formaldehyde	1.7-2.0	nil	--	--	175-300	50-125	1	8-23	electrical connectors, appliance handles
Urea and melamine formaldehyde	1.5-2.0	nil	--	--	190-200	35-75	1	7.5	countertops, dinnerware
Polyurethane	1.05	low	--	--	90-100	70	3-6	4	flexible and rigid foams for upholstery, insulation

Figure 3.35

Figure 3.34
Plastic identification flow chart. Identifying and distinguishing between thermoplastics and thermoset plastic based on their physical characteristics.

Figure 3.35
Polymer family and type. Common types of plastic based of plastic subsets.

Figure 3.36
Rome. Map of the processional avenues in Baroque Rome.

views that did not conform to confirmation bias. This trouble in choosing the correct dimensions was also due to the inability to understand the material. Without in-depth physical experience handling aluminum or polycarbonate, I could only assume how the assembly as a whole would react. For instance I simply assumed that straight rails would conform to the shape of the kayak, twisting along two axes without excessive force. For the half-scale aluminum model, I was forced to use extremely malleable 3000 series aluminum for the rails to ensure they would forcefully fit into the slots.

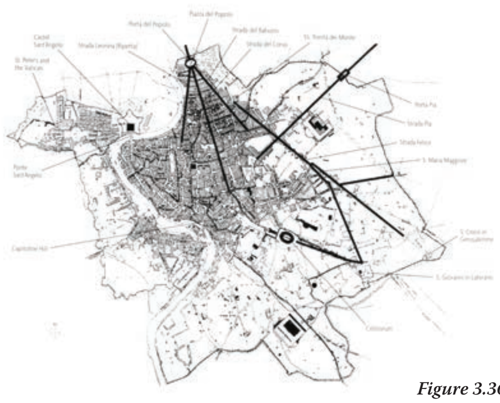

Figure 3.36

Troubles with materiality have a long pedigree in architecture. Few large-scale building projects before the industrial era had detailed working drawings of the precise sort CAD can produce today; Pope Sixtus V remade the Piazza del Popolo in Rome at the end of the sixteenth century by describing in conversation the buildings and public space he envisioned, a verbal instruction that left much room for the mason, glazier, and engineer to work freely and adaptively on the ground. Blueprints—inked designs in which erasure is possible but messy—acquired legal force by the late nineteenth century, making craftsmen these images on paper equivalent to a lawyer's contract. The blueprint signaled, moreover, one decisive disconnection between head and hand in design: the idea of a thing made complete in conception before it is constructed.[27]

Today, it is the opposite of ancient Rome, the designer holds the ultimate power and say, not the trades. Add education and you're left with an egotistical industry. In many cases, it is the architect versus the trades, the architect versus the engineer, and even more discouraging, the architect versus the user/owner. The transition from experienced trade to the educated designer is a cultural shift. Eventually, there will be a surge of young people choosing trades over arts, even if simply for the money, however the era of the tradesman equaling a craftsman is over.

If the hand that builds is no longer working in concert with the head that designs, what resolves the disconnect? How do you transfer faith and understanding, and execute a design? This geodesic isogrid kayak proves a good example. If someone were to purchase a flat packed kit to assemble the kayak, it must be accompanied by a build manual with drawings and clear instructions. In this sense, Ikea is a good example, although, Ikea plans for the lowest fabrication capabilities.

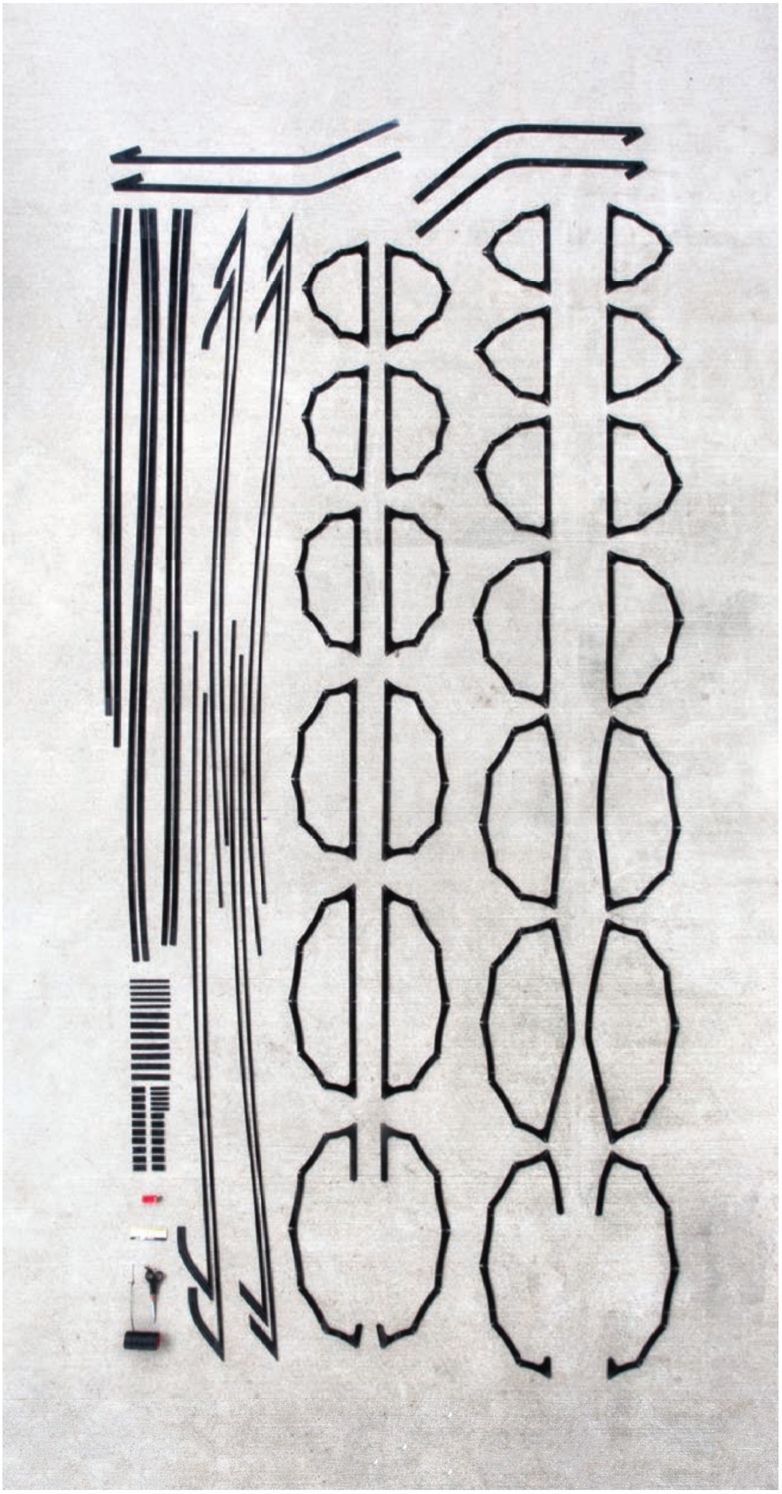

Figure 3.37
Kit of parts. Displayed are the parts and tools required to assemble a skin on frame kayak frame.

Most of their furniture is put together with fasteners that are difficult to over tighten or misuse.

A polycarbonate kayak assembled by capable hands would not look the same as one by inexperienced hands. Good design without capable fabrication equates to an undesirable product. Capable fabrication without good design equates to an undesirable product. Both aspects need to align to produce good work.

To achieve this, both the hand that designs and the hand that builds should have the characteristics described by C. Wright Mills categorizes as the qualities of a craftsman. This is not to be confused with someone who is skilled with the hands, but rather a mindset of approaching a practice, a style of work and a way of life as a whole.

The qualities include:

1. In craftsmanship there is no ulterior motive for work other than the product being made and the processes of its creation. The craftsman imagines the completed product, often even as he creates it; and, even if he does not make it, he sees and understands the meaning of his own exertion in terms of the total process of its production. Accordingly, the details of the craftsman's daily work are meaningful because they are not detached in his mind from the product of the work. The satisfaction he has in the results infuses the means of achieving it.

2. In craftsmanship, plan and performance are unified, and in both, the craftsman is master of the activity and of himself in the process. The craftsman is free to begin his working according to his own plan, and during the work he is free to modify its shape and the manner of its shaping. Work is a rational sphere of independent action.

3. Since he works freely, the craftsman is able to learn from his work, to develop as well as use his capacities. His work is thus a means of developing himself as a man as well as developing his skill. This self-development is not an ulterior goal, but a cumulative result of devotion to and practice of his craft.

4. The craftsman's way of livelihood determines and infuses his entire mode of living. For him there is no split of work and play, of work and culture. His work is the mainspring of his life; he does not flee from work into a separate sphere of leisure; he brings to his non-working hours the values and qualities developed and employed

Figure 3.38

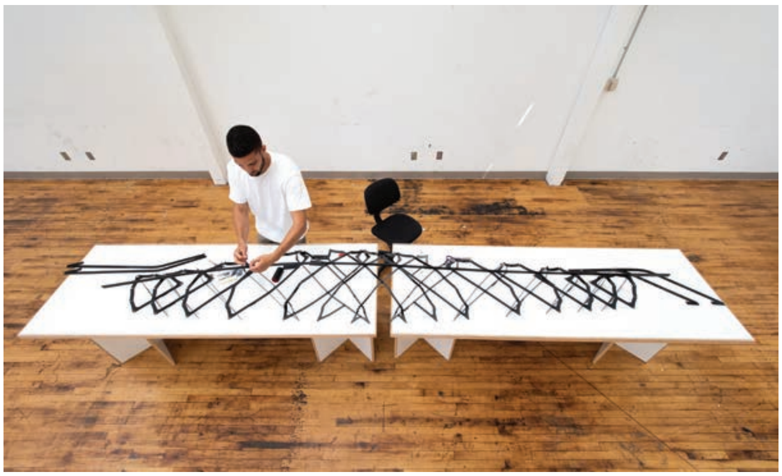

Figure 3.39

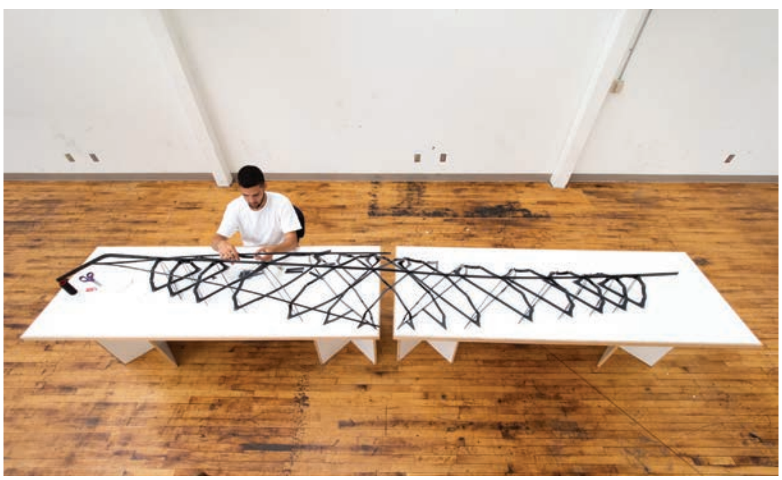

Figure 3.40

Figure 3.38
Kayak assembly. Assembling the intersecting carcass of polycarbonate sections.

Figure 3.39
Kayak assembly. Lashing the carcass through pre-cut holes.

Figure 3.40
Kayak assembly. Inserting the stern rail into the bottom slots of the exterior of the polycarbonate ribs. Then, lashing it in place.

Figure 3.41
Kayak assembly. Inserting the remaining rails and stitching the ends into the bow and stern assembly.

Figure 3.42
Kayak assembly. Using mending plates, I lashed the rails into one.

Figure 3.43
Kayak assembly. Once all parts are lashed, the polycarbonate kayak frame assembly is complete. Final weight is 8.36 lbs. Assembly time is 12 hours.

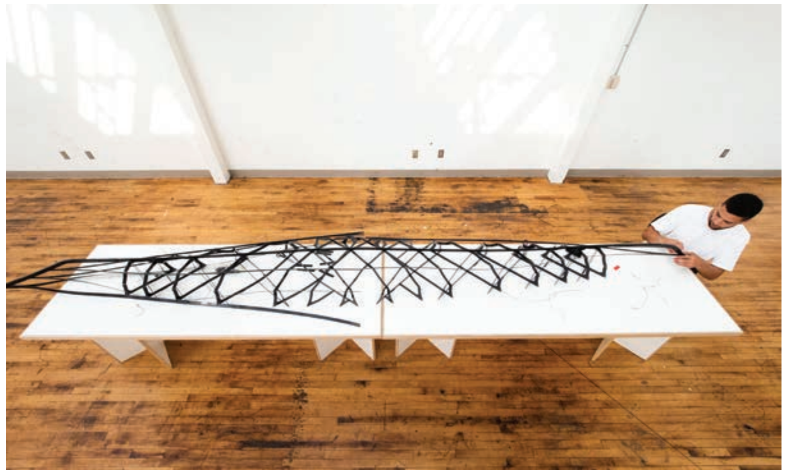

Figure 3.41

Figure 3.42

Figure 3.43

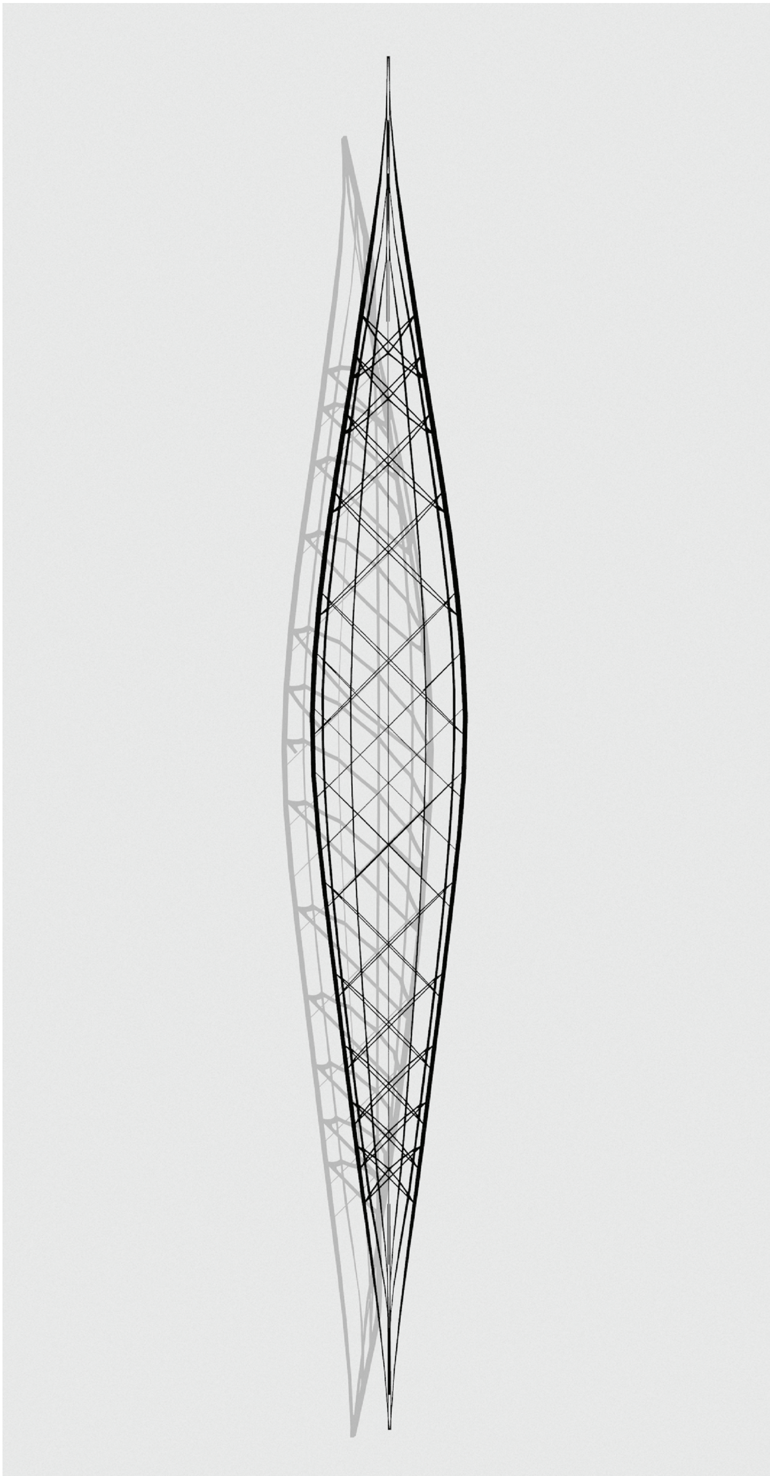

Figure 3.44
Polycarbonate Frame.
Rendering of the top view of the black polycarbonate skin on frame kayak.

in his working time. He expresses himself in the very act of creating economic value; he is at work and at play in the same act; his work is a poem in action. In order to give his work the freshness of creativity, he must at times open himself to those influences that only affect us when our attentions are relaxed.

5. Such an independent stratum of craftsmen cannot flourish unless there are publics who support individuals who may not turn out to be first-rate. Craftsmanship requires that such cultural workmen and such publics define what is first-rate.[28]

The designer must display the qualities of a craftsman in producing the plans for others to assemble. With new tools continuing to mask lack of manual talent, the designer should be able to control the details of design. The reliance on other people specialized manual skills for prototyping is no longer important if you combine thoughtful complex design, allowing for simple assembly. Labour is replaced with multifaceted digital design specifying form, while also managing economics, assembly, production, and the overall beauty of the thing. The designer should continue to be autodidactic and learning for the sake of bettering themself as a designer, fulfilling the model of a craftsman.

Within this framework, the design of the kayak should be an ever-evolving object and not remain stagnant once a current iteration is deemed acceptable by a supplier looking to sell them. I initially did not understand my disdain for the plastic kayak, yet through its consideration, I now understand I need both the current and the historic in tandem to make sense of the craft. I need the present to show the possibilities of mass-production, and the past to show the beauty of the craft. They both equally have purpose, and value in facilitating better design so long the designer adopts proper craftsmanship in executing design.

Figure 3.45
Polycarbonate Kayak. Photograph showcasing the interior volume that the structure produces.

Figure 3.46
Polycarbonate Kayak. The revised depth of the rails allow for the fabric to drape over the edge without an exaggerated distance from the carcass itself.

Figure 3.47
Polycarbonate Kayak. Revised mending plate connecting the seam of the ribs that facilitate the intersections.

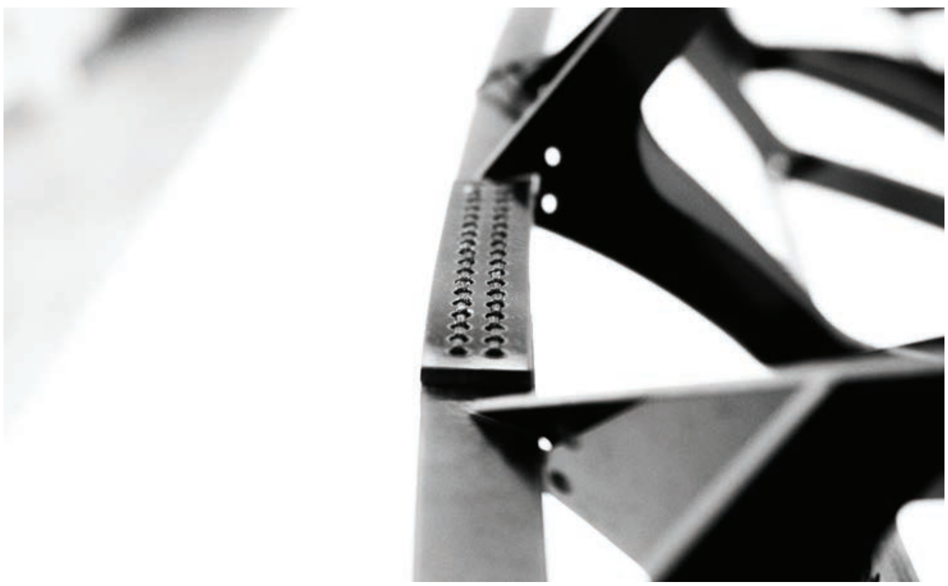

Figure 3.48
Polycarbonate Kayak. Mending plate of a rail that connects the bow and stern assembly as a whole.

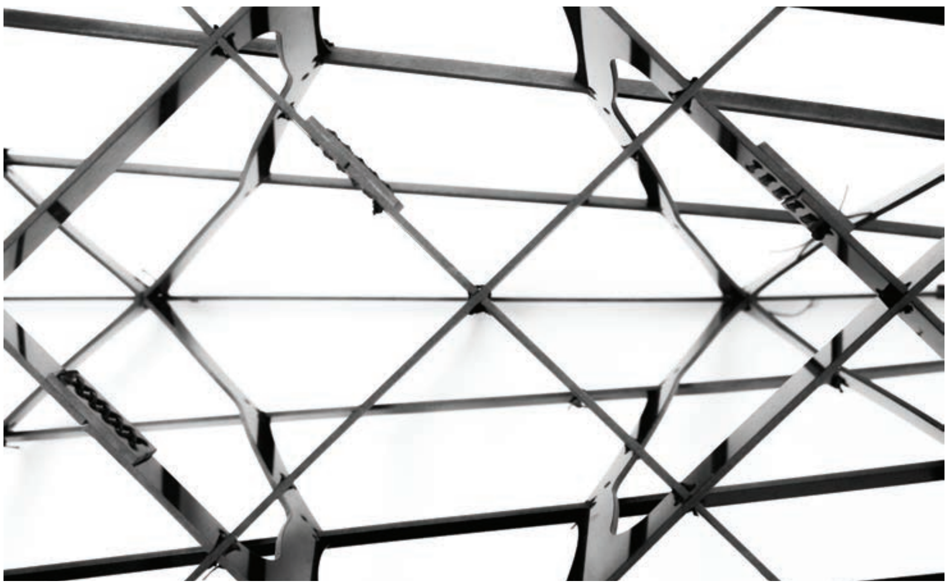

Figure 3.49
Polycarbonate Frame. Photo of the stern assembly from above

Figure 3.50
Polycarbonate Frame. Photograph of a slot joint and its lashing.

Figure 3.51
Polycarbonate Kayak. Photograph showcasing a mortise and tenon joint where two sets of ribs end to accommodate for a cockpit.

Figure 3.52
Polycarbonate Kayak. Stern assembly.

Conclusion

"What am I to do
with three kayaks."

The kayak relates directly to the body, it is an immersive experience and the performance feedback is immediate. My issues with the plastic kayak could have sat in my mind, and I could have mediated on why the kayak is the way it is. But, without creating the physical object, I would not have known how spruce, ash, douglas fir, 5-series aluminum, 6-series aluminum, or polycarbonate would react as structural material for skin-on frame kayak. Design speculation and hypothesizing takes you as far as your imagination, and eventually the design needs to be confronted by the limitations of the world.

And in designing and fabricating the three kayaks, I now better understand the design industry as a whole; how money is a driving force in manufacturing, how large-scale industry needs to streamline production and aim design towards the mean consumer to satisfy most people, how tradition is ignored in favour of fabrication efficiency and comfort. Custom design may take longer, and may not produce a better outcome, but mass-manufactured products leave no room for variance, whereas for custom design, variance is sought-after.

It is possible to design and fabricate a more aesthetically beautiful kayak with the zeitgeist of a traditional qajaq that rivals the commonplace kayak, but there are trade-offs. With plastic as a material being so robust, I could never design a kayak as durable. The durability of my final skin on frame kayaks comes from replaceable parts, rather than the toughness of the moulded material.

Looking at the work of Neff, Prouvé, Piano, Barnes, each designer (while working within a similar design territory as the kayak engineers), produces the best possible product given their available technology. There understanding of material properties produced dynamic design details that left no room for additional embellishment of form.

I am striving to make a better kayak. I do not know why. It is not for myself. I do not enjoy kayaking. I never have. I became obsessed with a thing I was unfamiliar with. Driven by curiosity, maybe confusion, or even hatred. It is not for myself or for a superior, but for the sake of the kayak and its evolution as an artifact. I'm doing it in attempt to do good work for the sake of the artifact rather than alternate motives.

Endnotes

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2 Ibid., 50.

3 Jean-Louis Cohen, "Le Corbusier's Modulor and the Debate on Proportion in France", http://dx.doi.org/10.5334/ah.by, (2014).

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