Metaphor in the Making:

Comparative methods of representation in physical architectural models.

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Abstract

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Metaphor enables us to understand concepts in terms of other concepts. Architectural representation is a metaphor that stands in place of the design being represented. This metaphor allows us to structure our thinking around something tangible while thinking about something that is less tangible. This investigation explores the use of architectural models in developing concepts for architectural design. It explores the physical operations that are used in fabricating models in order to better understand how those physical operations shape the metaphors that we use in architectural design. Components of a model are analogous to components of a building. The choice of how a component is developed in a model effects the development of the design. The objective of this thesis is to create a framework of physical models that aids in decisions regarding the choice of model type and fabrication method. What model will be most effective at a specific point in the design process? What model will best address a specific problem?

figure 1.1

Chapter 1

Introduction: metaphor in the context of architectural models

All architectural representation is metaphor. (Hart, 2012) We create models that stand in place of an unrealized construct. We often talk about the metaphor behind an architectural concept, but any architectural representation is itself a metaphor for something that does not yet exist. It is a thing that stands in place of something else.

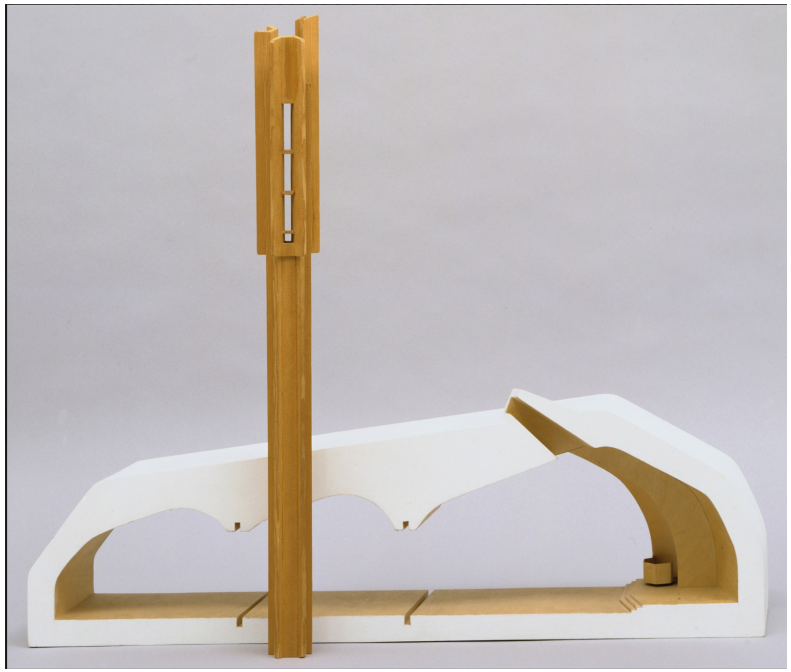
According to the contemporary theory of metaphor (Lakoff 1987; 1993), metaphor is what structures human conceptual systems. Metaphor is at the heart of how humans think, perceive, categorize experiences and concepts. These things do not exist within the human mind without metaphor.

A conceptual metaphor is a metaphor in which one idea is understood in terms of another. Metaphor comes from the Greek word metaphora which means transfer. By transferring one concept to another we can understand one concept in terms of the other. This ability to let one concept stand in for another is what makes conceptual metaphor so powerful. A metaphor stands as two juxtaposed things that are clearly different, but with enough common characteristics that they can be understood in relation to each other.

Concepts are understood as a primary case on which we structure our experience. Every person has a theory of the world that is furnished by these concepts. The way that a person understands the world is based on the metaphors that they use to conceive it. Lakoff argues that all of our metaphors go back to primary physical experiences. Our cognition is rooted in our physical experience. (Lakoff, 1999) Based on this notion of the embodied mind it follows that the way we think about architecture is rooted in physical acts of making.

In his book The Thinking Hand Pallasmaa says that “The hand-eye-mind connection in drawing is natural and fluent, as if the pencil were a bridge that mediates between two realities, and the focus can constant-

figure 1.2 Model of Alvar Aalto's Church of the Three Crosses



ly be shifted between the physical drawing and the non-existent object in the mental space that the drawing depicts." (Pallasmaa, 2009). The act of drawing clearly builds a metaphor that allows the designer to understand a non-existent object in terms of the drawing. The same notion of the thinking hand developing a representation can easily be extended to architectural models.

A model stands in place of the thing modeled. It is a metaphorical representation that stands as an analog to something else. All its parts are comparable to parts in the thing modeled. The designer must choose what parts are relevant to the model they are creating and how to abstract those parts. The intention of the model will drive many of these decisions. If a model is intended to help understand how a building shapes the space around it, it will be approached very differently than a model exploring the internal character of an important space within the building.

Architectural models are themselves designed things. The design decisions that are made in the modeling process are decisions about the design process itself. In order to make these decisions a designer must first decide what the intention of the model is. Based on that intention the designer can make decisions about what components needs to be modeled and what those components stand in place of in the design. The model forces the designer to make decisions on what to abstract and how much to abstract it.

As a noun a model is a physical manifestation of a thought. It is the embodiment of the idea and it shares enough with the idea that it is modeling that we understand the thing modeled through the model. When used as a verb to model is to think. The act of modeling in architecture is an act of thinking.

figure 1.3 Model of Alvar Aalto's Church of the Three Crosses

Components of a model are analogous to components of a building. The choice of how a component is developed in model affect the development of the architecture. A model stands in place of something that it is not. A model identifies and simulates key characteristics of the thing modeled.

figure 1.4 Photo inside Alvar Aalto. Church of the Three Crosses, Vuoksenniska, Imatra, Finland.

Chapter 2

Material and Fabrication: the physical methods used to construct metaphor in architecture.

Architecture is the development of a language of making that creates space. Models are an essential tool in the development of an architectural language. That language is rooted in the choices of material and methods of fabrication. These choices establish the metaphor that that shapes the development of a project. The literal shape and nature of the model is dependent on these choices.

In order to understand how architects use models in the development of their architectural metaphor I began by investigating the models of four prominent Architects all of whom use models extensively within their practice. The Architects I selected were Alvar Aalto, Allied Works, Kengo Kuma and Patkau Architects.

figure 2.1 Model of Alvar Aalto's Church of the Three Crosses

Alvar Aalto

Alvar Aalto is a prominent 20th-century Finnish architect. Aalto used models extensively both in his architectural work and his furniture design. His models are primarily made in one material which is wood. Within the material he explores his designs at all scales pushing the wood to say many different things depending on the intent of the model.

figure 2.2 Material study by Alvar Aalto

figure 2.3 model by allied works

Allied Works

Allied Works is a Portland-based architecture firm. Models are an essential part of their design process, they are very experimental in their use of materials in making models. (Allied Works, 2018)

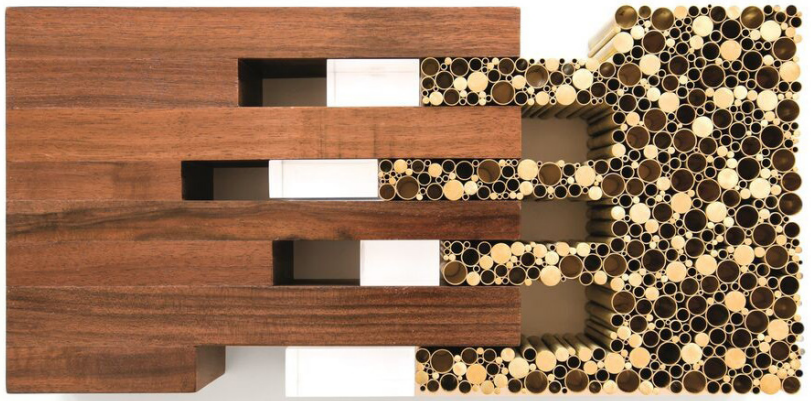


figure 2.3 model by allied works

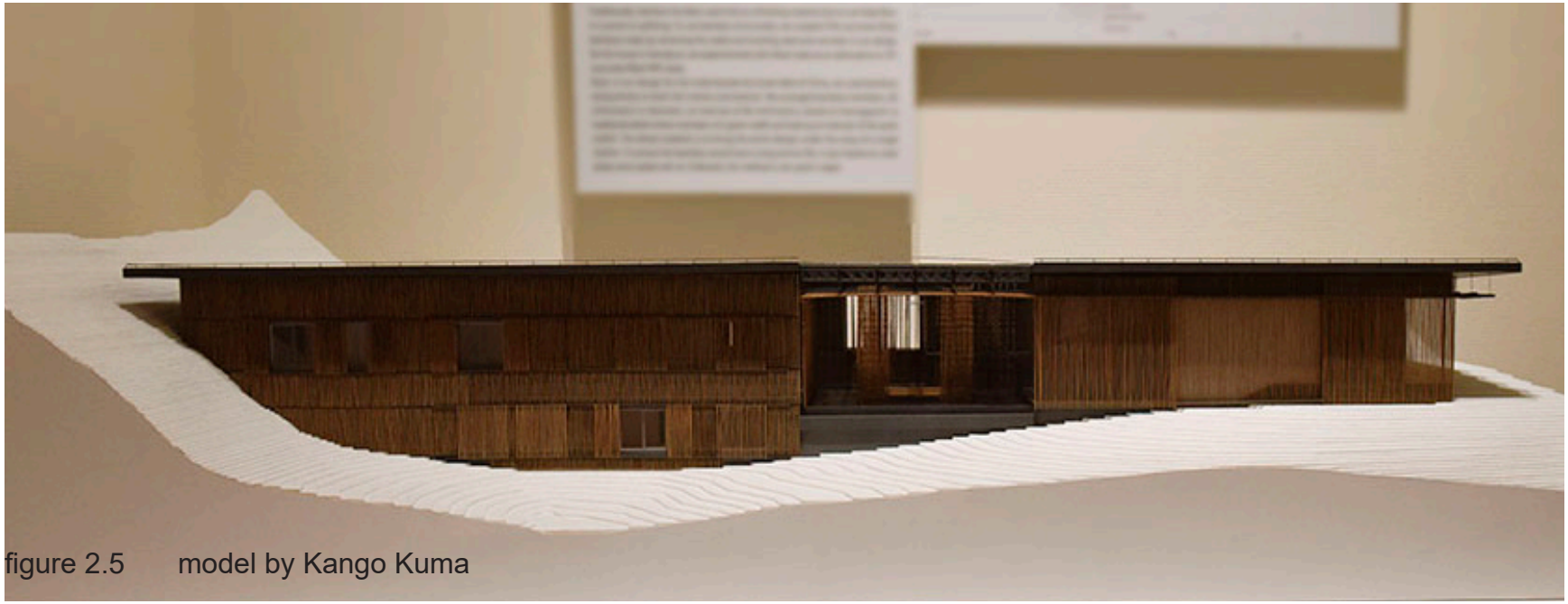


figure 2.5 model by Kango Kuma

Kengo Kuma

Kengo Kuma is a Tokyo-based Pritzker Prize winning architect. Kuma is well known for his models and their material character. He has written extensively about the role of materials in making. To Kuma different materials have different ways that they want to be organized and he said that “materials whisper and talk”. (Kuma, 20018) Certain materials lend themselves to certain operations. Many of his models are rooted in the same idea of material and operation. He strongly connects the material character of his models to the material character of the buildings that they represent.

figure 2.6 model by Kango Kuma

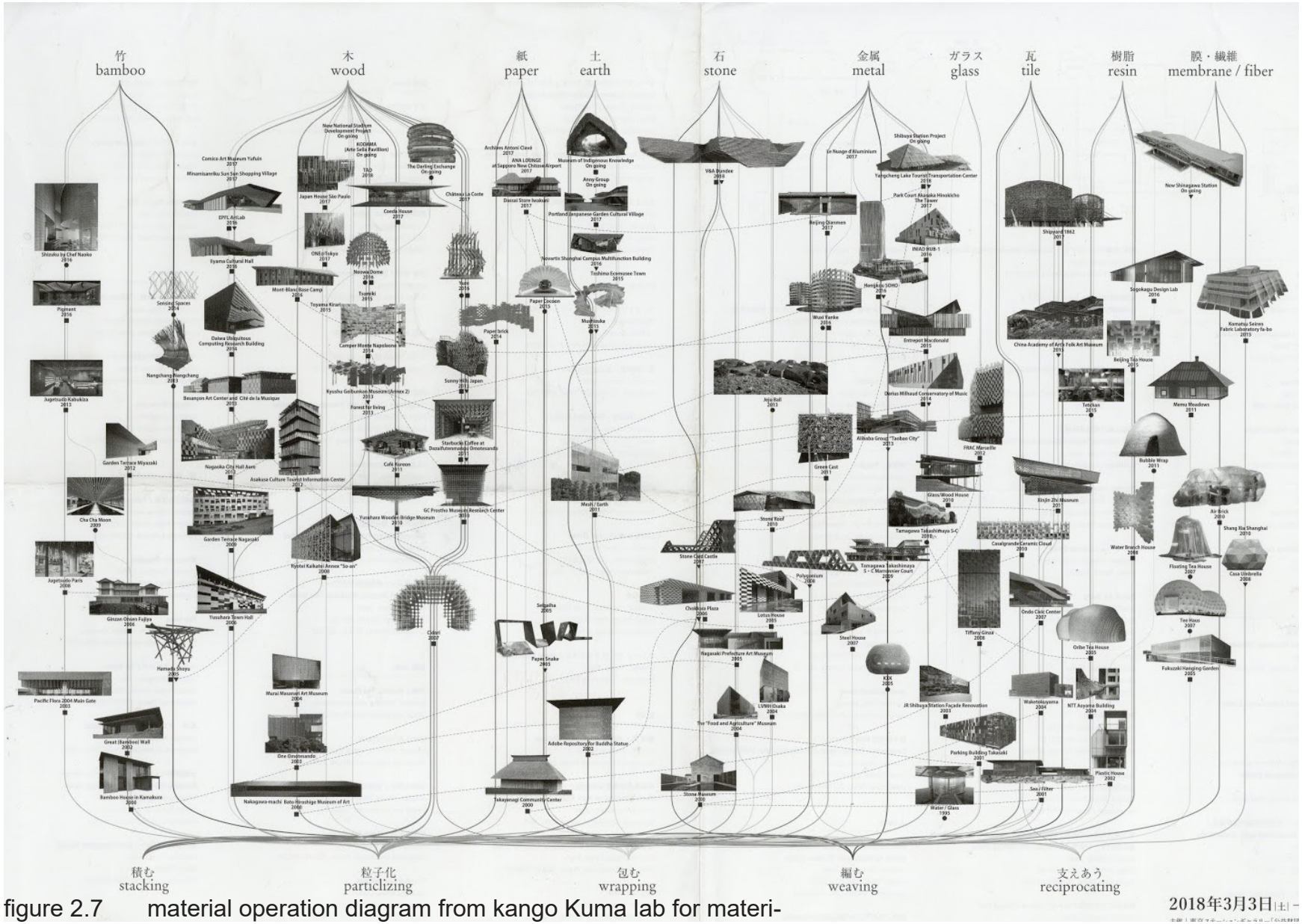


figure 2.7 material operation diagram from kengo Kuma lab for materi-

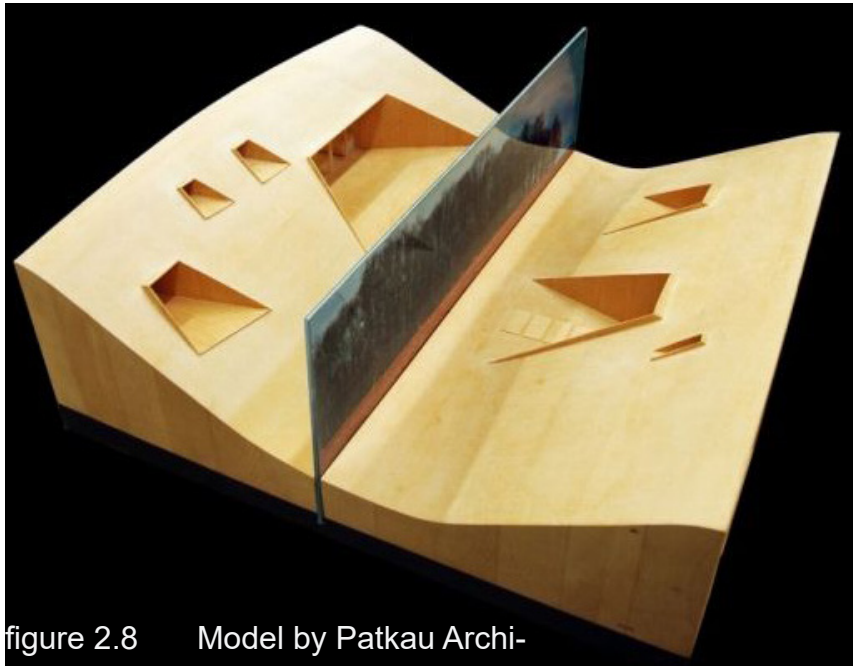


figure 2.8 Model by Patkau Archi-

Patkau Architects

Patkau Architects is a Vancouver-based architecture firm. They describe themselves as an architecture and design research studio. Their work ranges from insulation are two large urban projects. (Patkau, 2017) They make heavy use of models in their practice and enter many models into exhibitions. In their book Material Operations they have documented much of their research. Their work focuses around their exploration ofmaterial behavior, systemic operations and assembly processes.

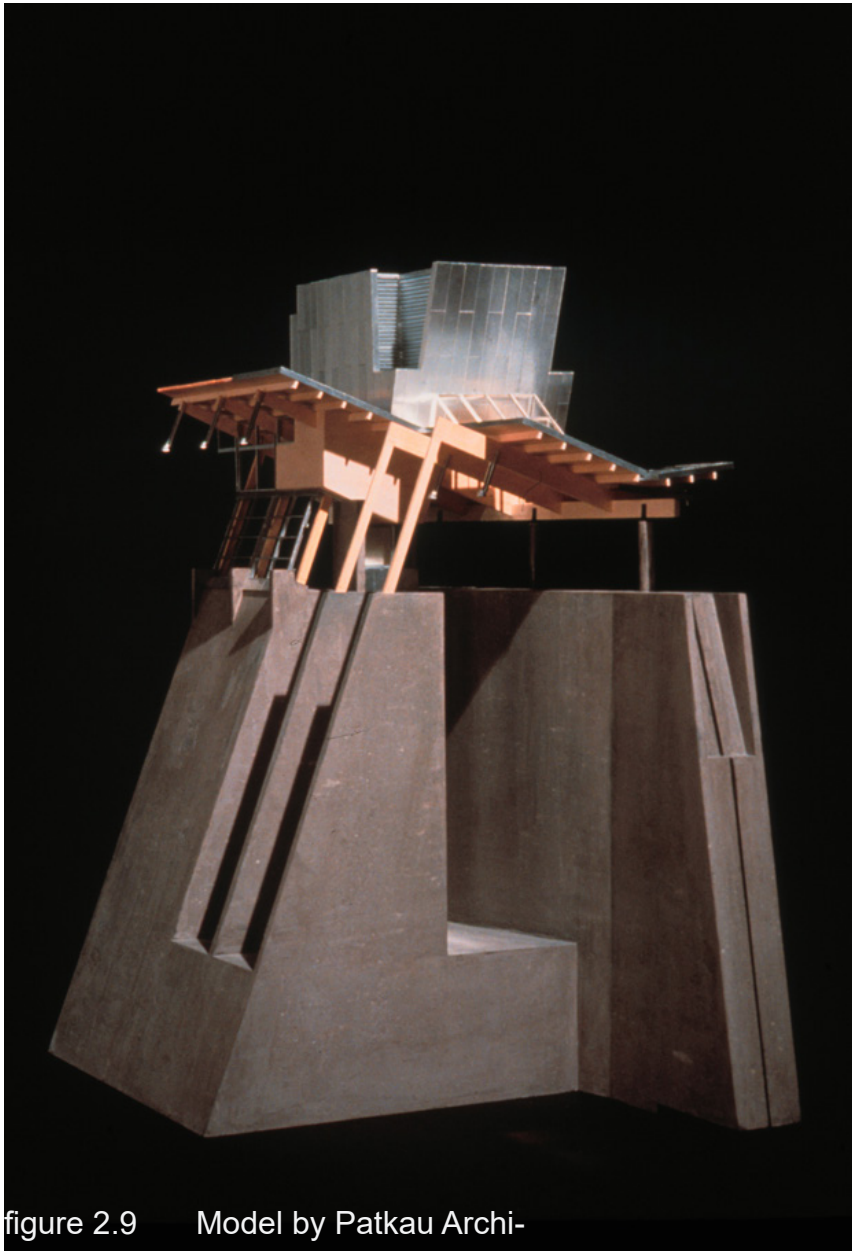
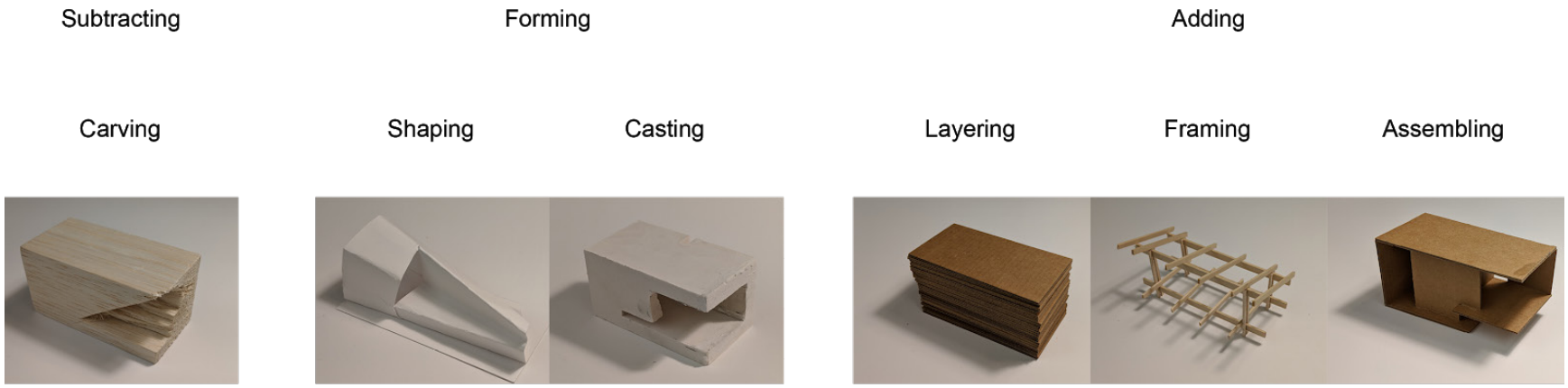


figure 2.9 Model by Patkau Archi-



Through analyzing the methods of model making employed by these architects I established a system of classification for the operations used in fabricating models. The way I approach this classification was heavily inspired by the thinking of Kengo Kuma and Patkau Architects. This system of classification has three primary operations which are adding, subtracting and forming. There are also six secondary operations. Under adding we find framing assembling and layering. Subtracting is carving and forming contains casting and shaping.

figure 2.10 diagram showing the six operations of physical modeling

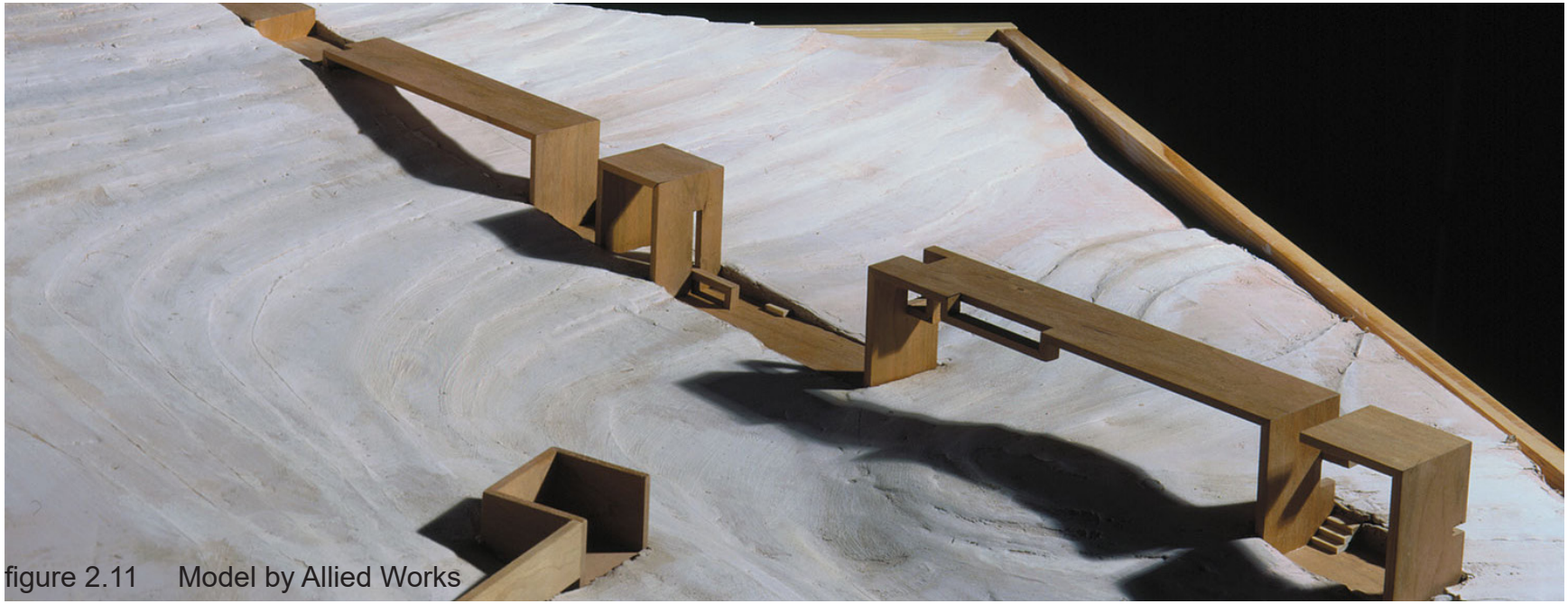


figure 2.11 Model by Allied Works

Adding is one of the most accessible and fundamental operations. A child building a castle out of blocks is an adding operation. So too is the construction of a stone cairn or a lean to. Adding is the accumulation of parts into a whole. There are three operations within adding, framing, layering and assembling.

Assembling is the process of building up a system of interlocking plans. it lends itself to the creation of corners and enclosure.

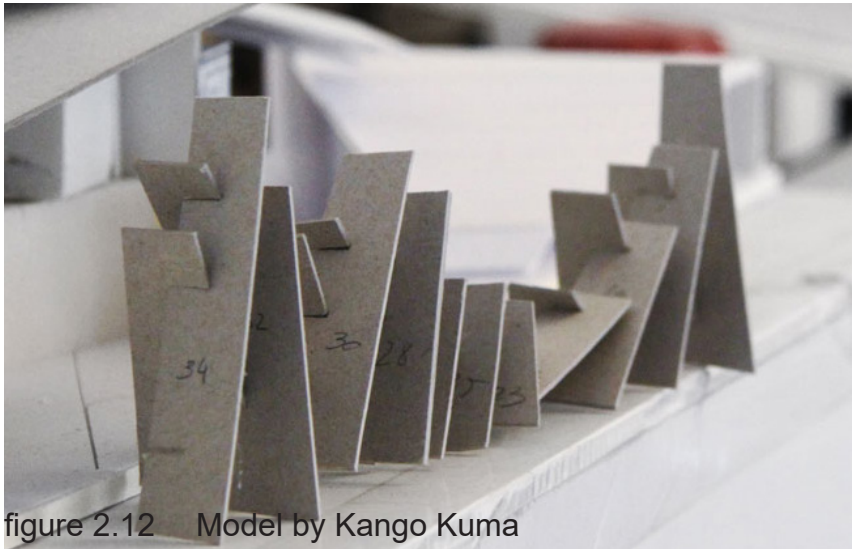


figure 2.12 Model by Kango Kuma

figure 2.13 Model by Kango Kuma

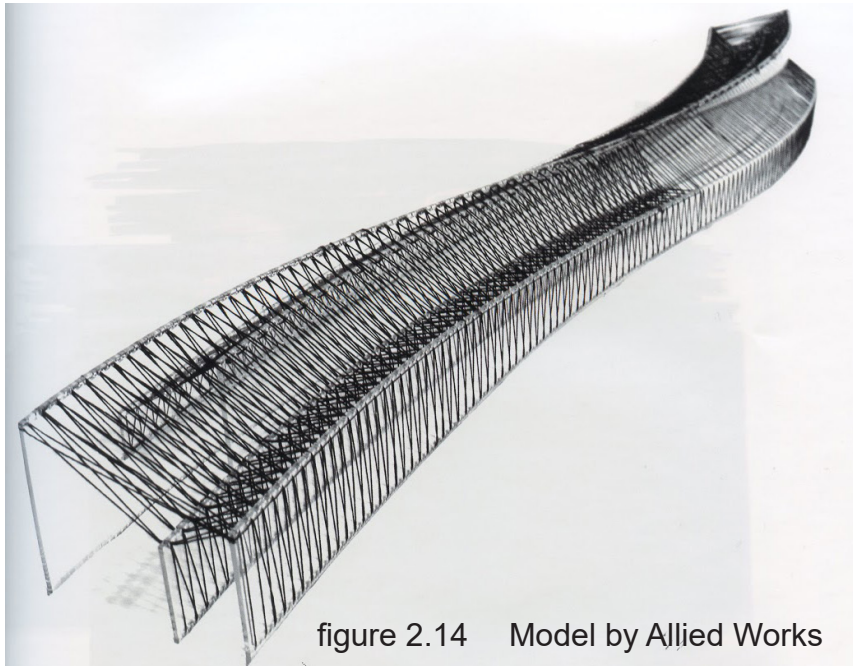


figure 2.14 Model by Allied Works

Framing the organization of linear elements into a system of joints. Building the truss would be a framing operation as would raising a tepee.

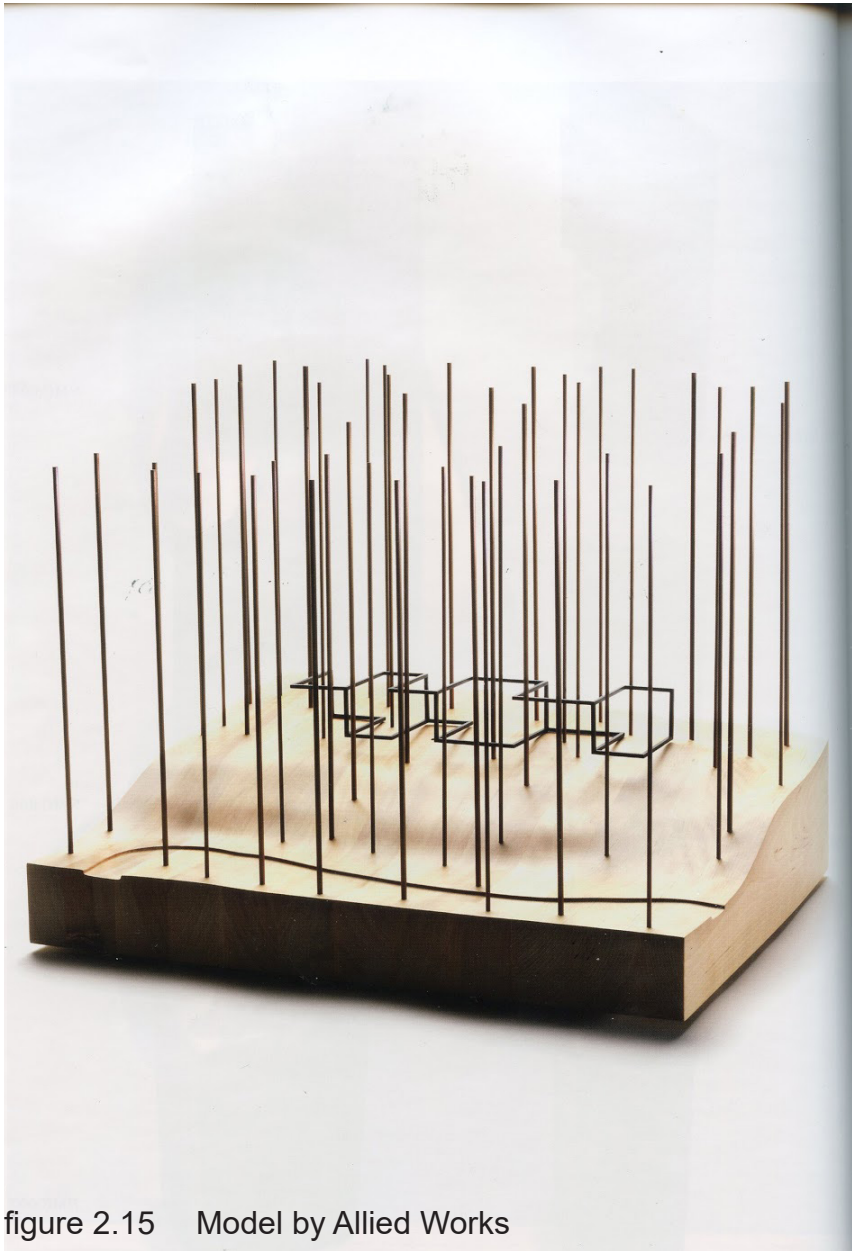


figure 2.15 Model by Allied Works

figure 2.16 Model by Kango Kuma

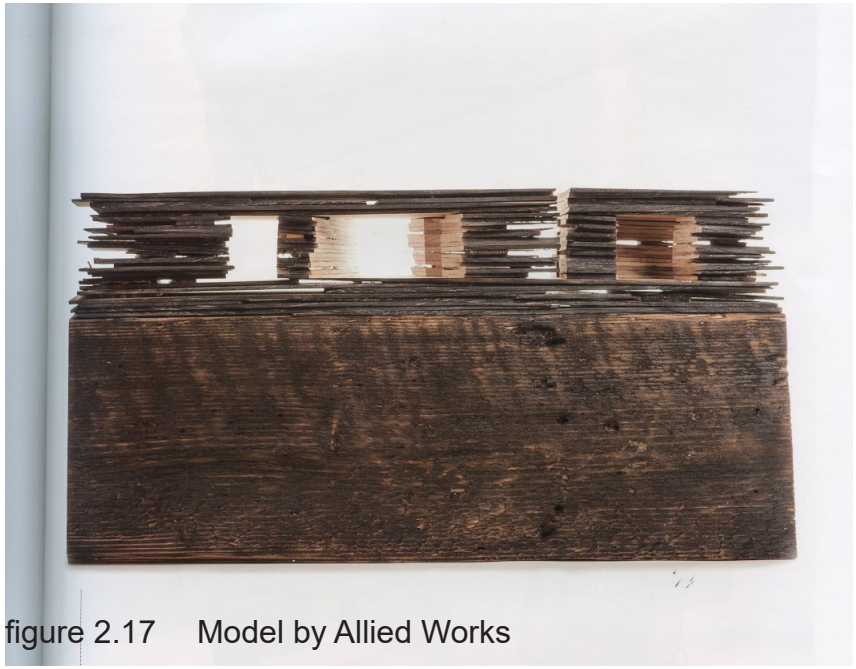


figure 2.17 Model by Allied Works

Layering is the act of adding material directly atop material. Common layering operations are laying bricks and the stacking of stone.

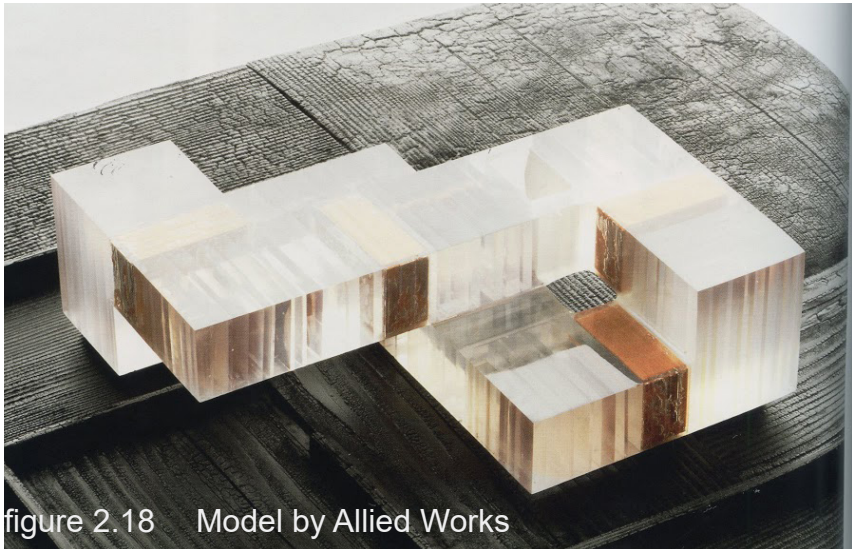


figure 2.18 Model by Allied Works

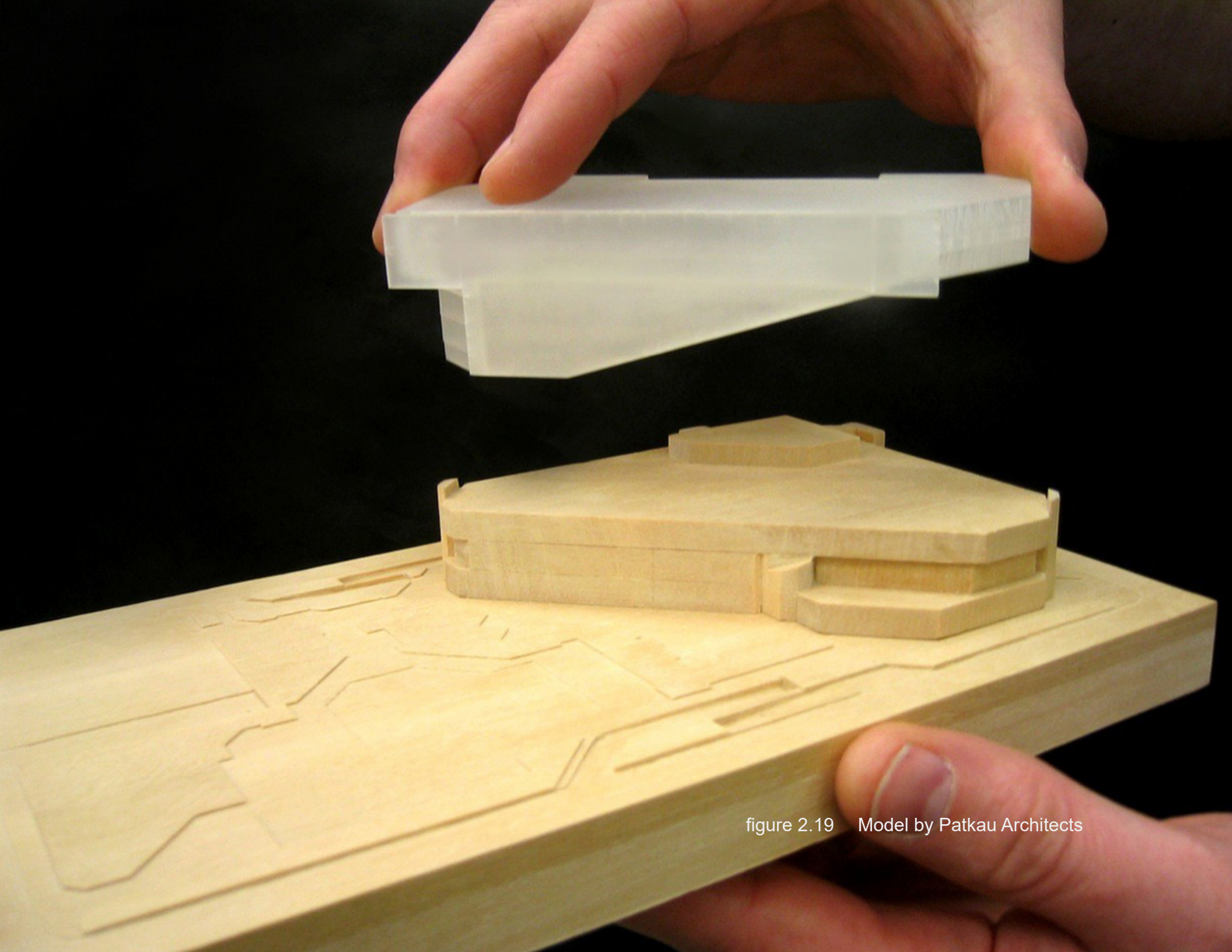


figure 2.19 Model by Patkau Architects

figure 2.20 Model by Allied Works

Subtracting is the most elemental operation is the removal of material from a whole. Digging a hole is a subtracting operation and so is carving a block of wood. Every subtracting operation is some type of carving.

figure 2.21
Model by Allied Works

figure 2.22 Model by Patkau Architects

figure 2.23 Model by Allied Works

Forming is the reworking of material into new forms. There is no loss or gain of material, but rather a reorganization. Kneading bread dough and forming pudding would both be forming operations. The operations that we find in forming are casting and shaping.

Shaping is the act of reworking a material into a new shape. Bending, folding and sculpting would all be examples shaping

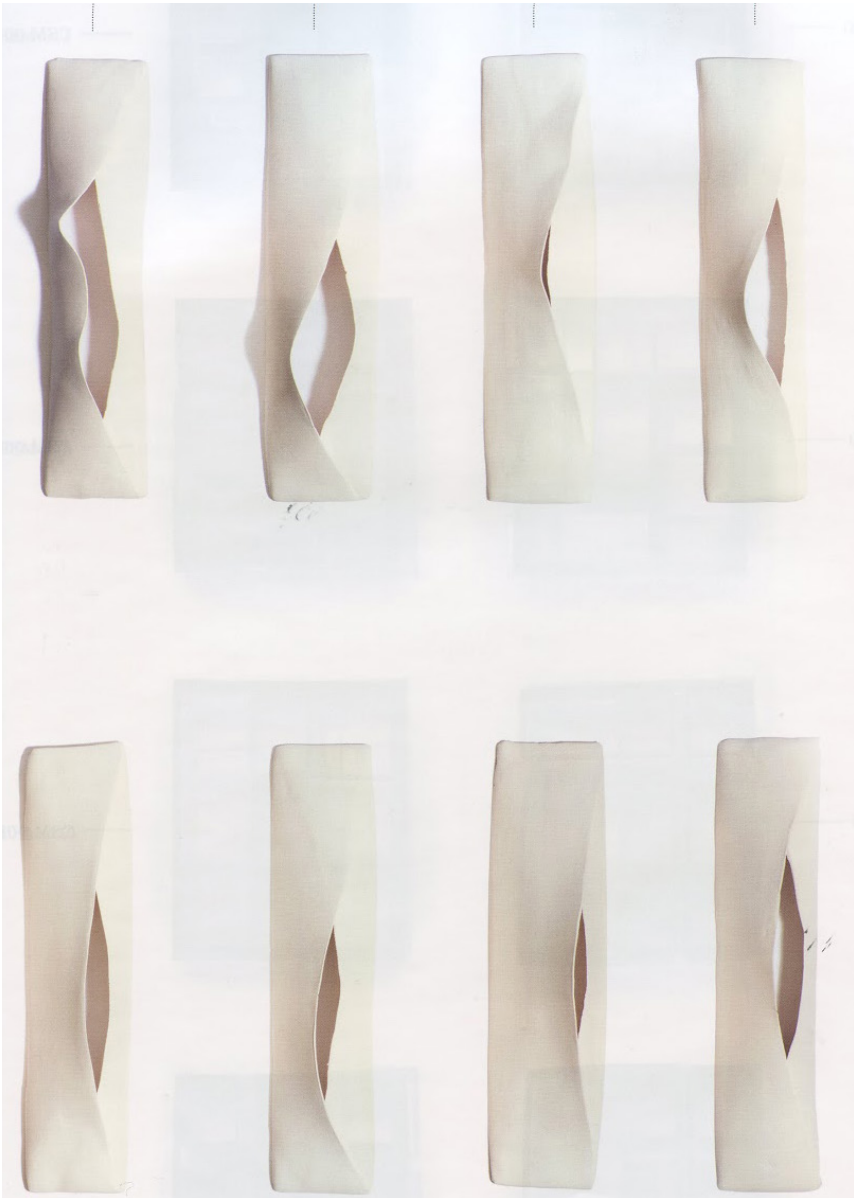


figure 2.24 Model by Allied Works

 figure 2.25 Model by Patkau Architects

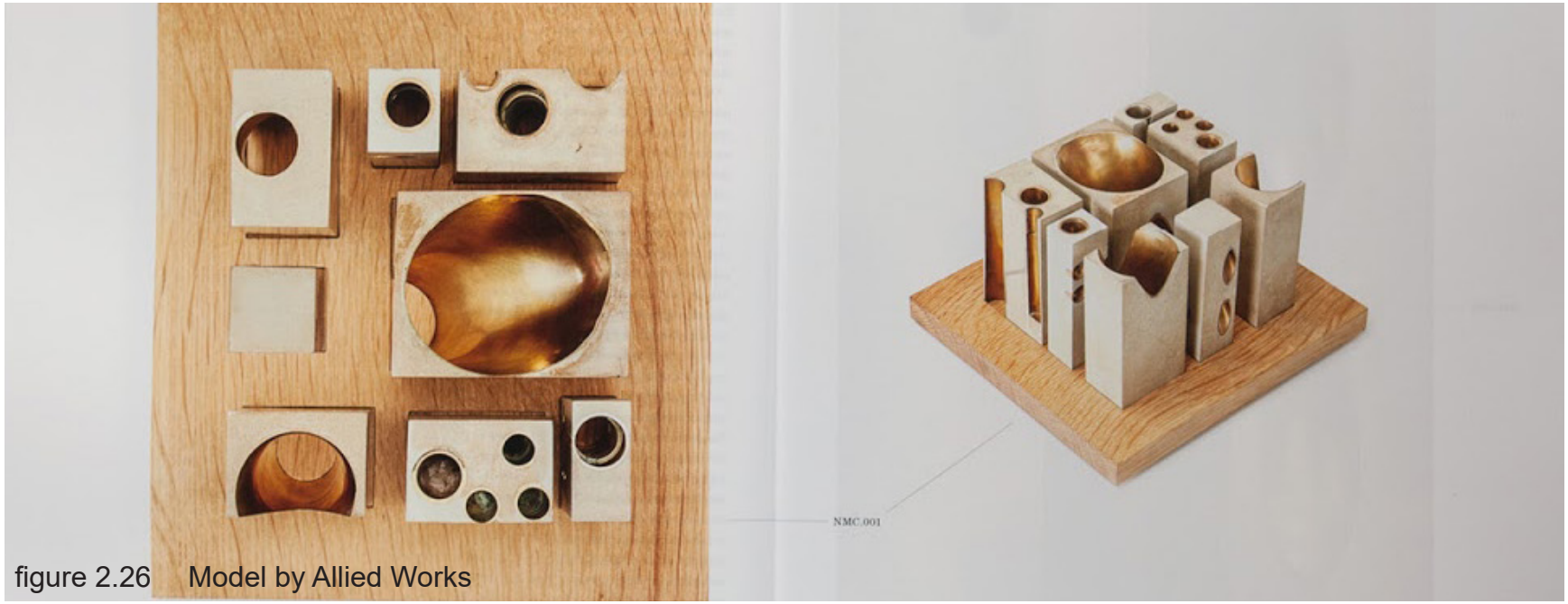


figure 2.26 Model by Allied Works

casting is an operation in which a liquid material is poured into a mold or form work and then solidifies. Making bars of soap and pouring a concrete foundation are both casting operations.

figure 2.27 Model by Patkau Architects

figure 2.28 Model by Allied Works

All models are made using some combination of assembling, layering, framing, carving, casting and shaping. While some models are fabricated with a single Operational method many are hybrids of multiple Operations.

The choice of fabrication method has a profound impact on the characteristic modeled during the models Construction. Some model types will tend towards specific methods of fabrication. These operations are the physical basis for the metaphors of modeling

figure 3.1 diagram showing the range of models from conceptual to real.

Chapter 3

Categories:

Many architectural models are hard to classify into only one type of model. However, all the models examined in this study fell on a spectrum from concept to real. Models on the concept side of the spectrum are the developing of an architectural idea that is often analogous to something abstract. On the real end of the spectrum, models represent the design as a realized thing. The metaphor in these models usually holds a direct analogy between the components of the model and the components of the design.

There is very little consistency in the in the names used for categorizing architectural models. I've drawn from several sources and created my own set of categories for this exploration. (Congdon, 2010) (Janke, 1978) (Knoll, 2007) (Mills,2005)

Understanding the intended audience for a model is an important part of understanding modeling and decisions about the design of the model.

Models designed for presentations are intended primarily to communicate the project someone outside of the design process. In contrast study models are directly intended to work out and clarify design decisions. They are primarily used within a design team and are often never shown outside of the design process.

categories of intent

categories of intent are characterized by the intention of the model. Is the model meant to understand the underlying idea of the design or is it a study in spatial composition. There are many categories of intent ranging from concept model to tectonic model.

Categories of intent

Concept models

Composition model

Massing models

Volumetric model

system models

Tectonic models

Structural model

Atmosferic

Interior model

Daylighting model

categories of extent

categories of extent are characterized by how much scope is represented in the model. When creating a model the designer must decide how much context it is useful to include based on the intention of the model.

Categories of the extent

Site/context models

project model

Sectional model

Facade model

Detail model

Component model

figure 3.2 Model by Allied Works

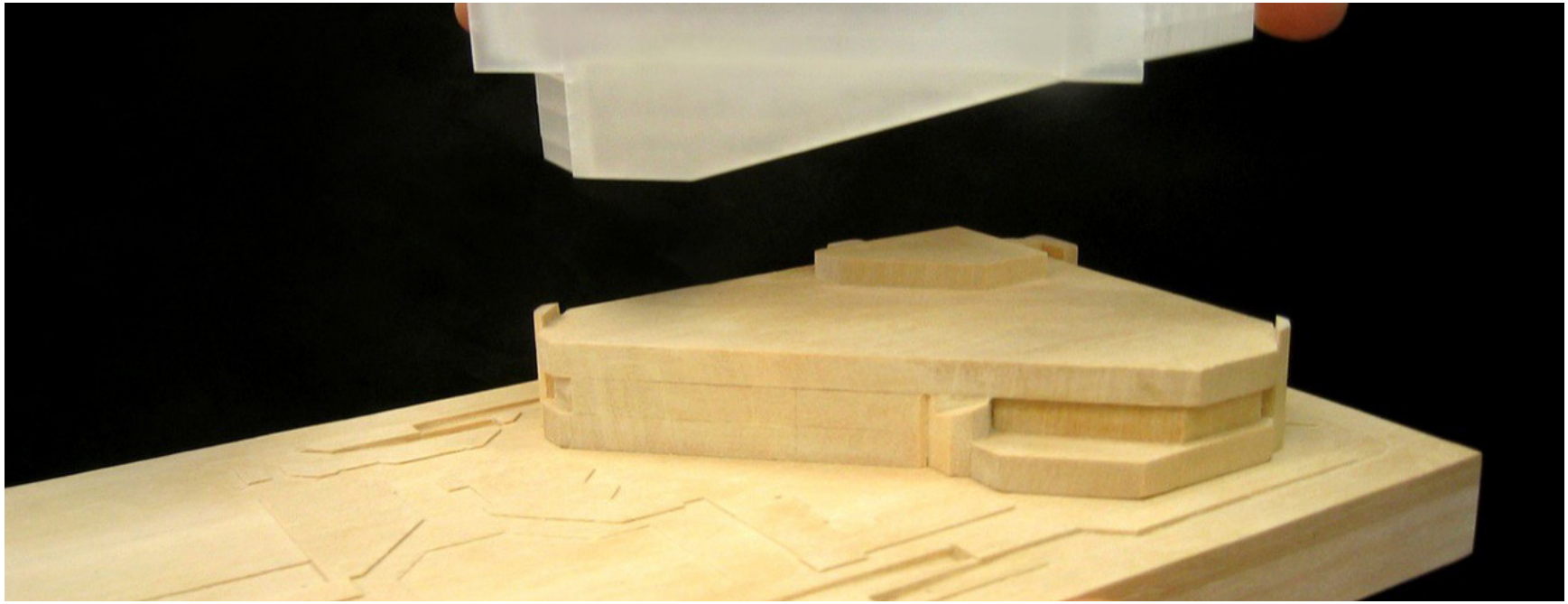
categories of intent

Concept models

A concept model is meant to develop and illustrate the underlying idea of a design. It establishes a conceptual framework that holds the design together. The concept model is often used throughout the design process to test whether the current work is in keeping with the concept.

figure 3.3 Model by Patkau Architects

figure 3.4 Model by Patkau Architects



Massing models

A massing model depicts a project presence on a site. It is used to develop and understand issues of scale proportion and contextual relationship. The Massey model is often used in urban projects to understand buildings impact on its Urban context. How does it shape the public realm, how does it affect view corridors, how does it relate to the massing of surrounding buildings etc...

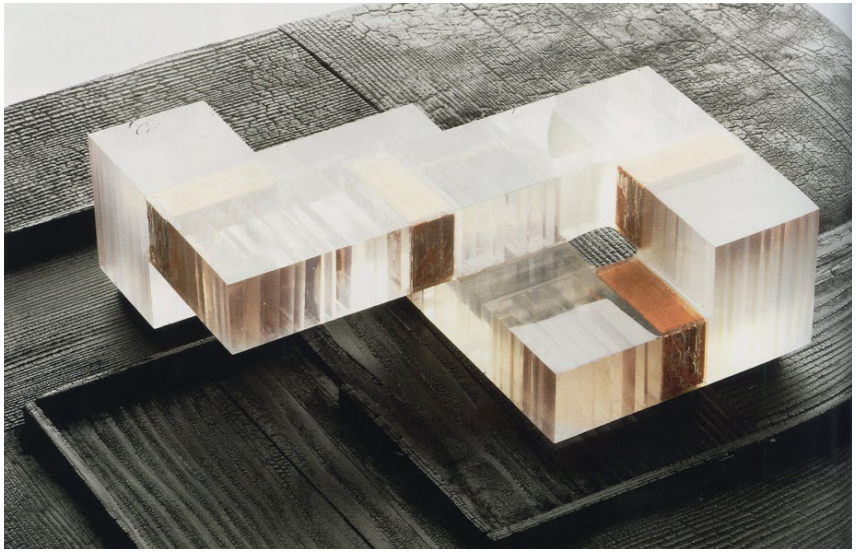
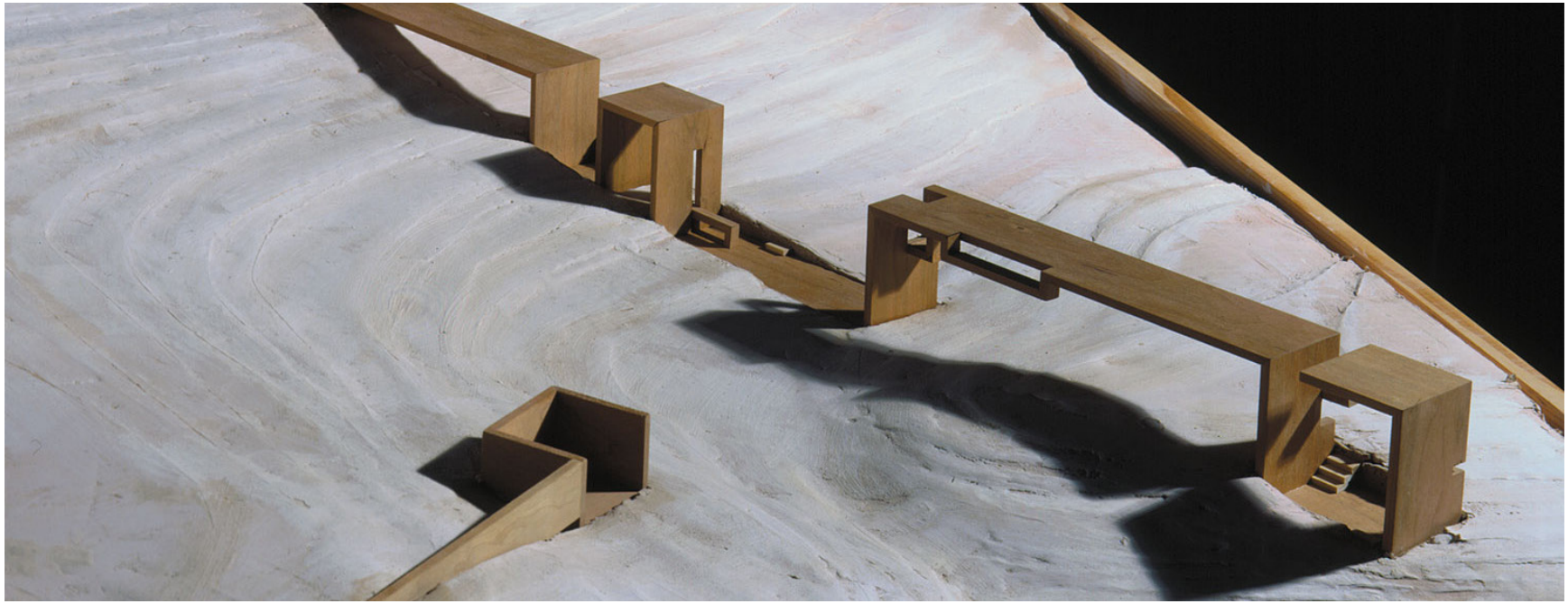


figure 3.5 Model by Allied Works

figure 3.6 Model by Allied Works



Volumetric model

Volumetric models are meant to explore and understand the division between positive and negative space and the boundaries between spaces. It constructs the negative and positive volumes of a space and illustrates how those volumes relate to one another. This might also extend to how volumes that are interior to a project relate to volumes that already exists Within its context.

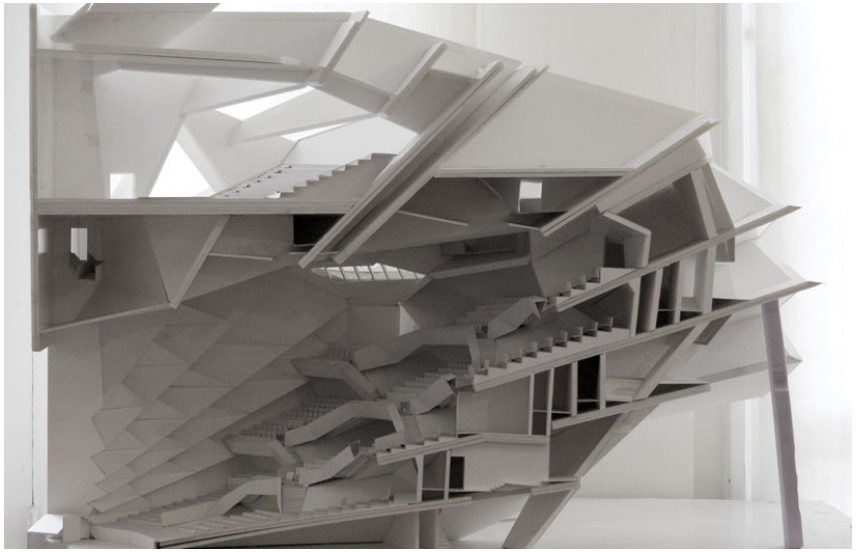


figure 3.7 Model by Kango Kuma

figure 3.8 concept model by Kango Kuma

Tectonic models

Tectonic models are meant to demonstrate the assembly of a building's components. They help to develop and illustrate the hierarchy of parts within a project.

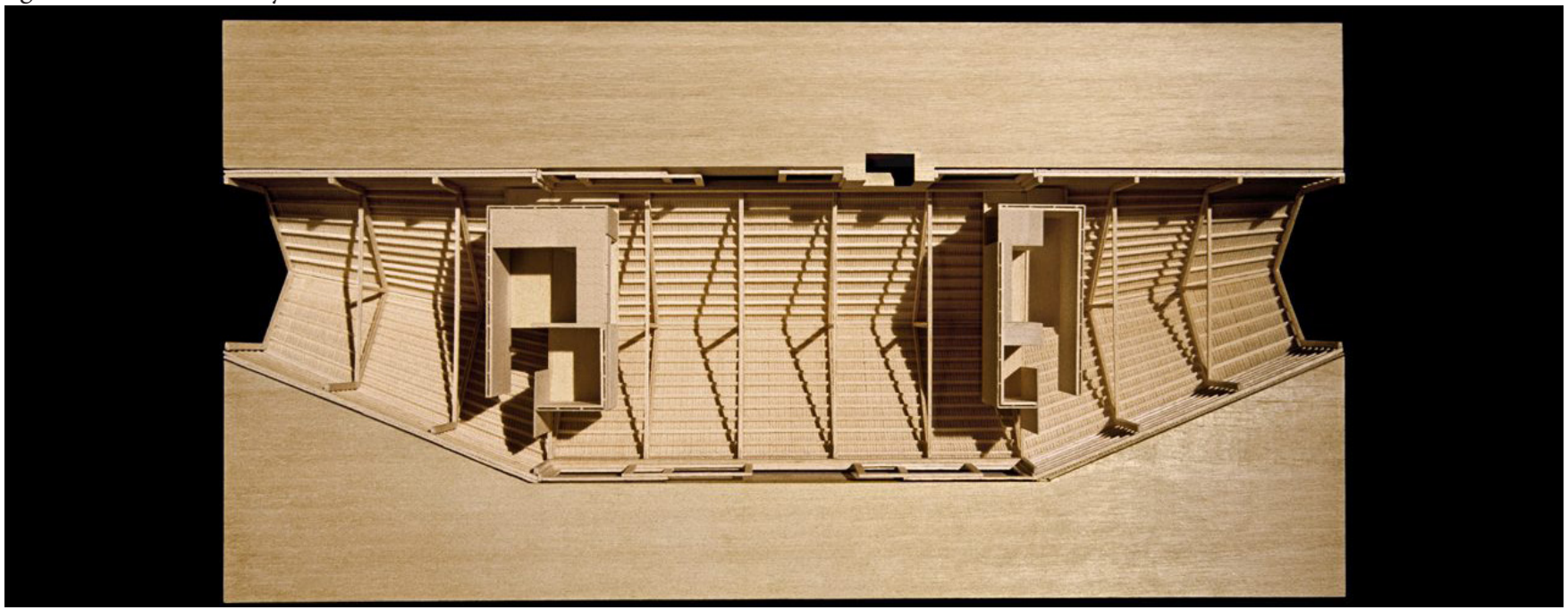
figure 3.9 Model by Patkau Architects

figure 3.10 Model by Patkau Architects

Structural model

Structural models explore and illustrate be structural logic of a project. It demonstrates what parts of a structure are in tension and compression. It also illustrates what type of structural systems are being implemented (bulk active, form active or vector active.) A structural model has a direct analog between the elements of model and the structural elements of the building it represents.

figure 3.11 Model by Patkau Architects



Interior model

An interior model details the experiential qualities of an interior space.

figure 3.11 Model by Patkau Architects

Daylighting model

Daylighting models are a type of interior model used to understand the distribution and quality of light within a space. The behavior of light is scaleless and so a day lighting model can represent the behavior of light with extreme accuracy. An advantage that a physical daylighting model has over digital daylighting models is that the eye of the Observer will react to The Light Within the space in the same way as it would at full scale. This makes it extremely useful in understanding the experiential qualities of light.

figure 3.13 Model by Allied Works

Categories of the extent

Site/context models

Site models are intended to show the relationship between a potential project site and its greater context. They address issues such as slope, vegetation, view corridors solar exposure Etc…

figure 3.14 Model by Allied Works

Project model

a project model is a model that ends at the project boundary. It shows the entire extent of the area being designed, but no external context. Often project models will be made in such a way that they can be inserted into a Site/context model.

figure 3.15 Model of Alvar Aalto's Church of the Three Crosses

Sectional model.

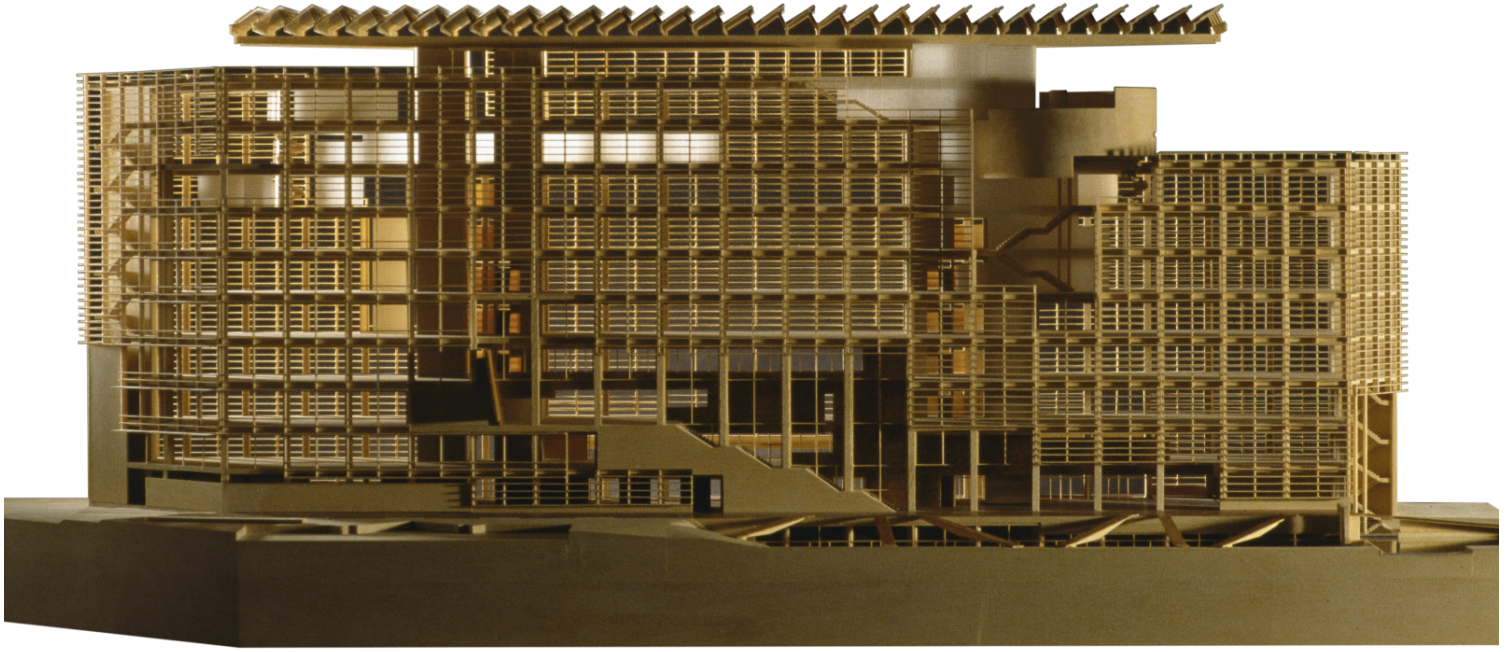
A sectional model it's created with a sectional cut through part of the project. It reveals sectional characteristics that might otherwise be hidden.

Detail model

The detail model focuses in on a specific Construction detail. It can be used to help a designer understand how the detailed would be constructed and illustrate its construction to a builder.

figure 3.16 concept model by Kango Kuma

figure 3.17 Model by Patkau Architects



Facade model

A facade model explores the articulation of a building facade independent of the building.

figure 3.18 Model by Patkau Architects

Component model

A component model focuses on aspect of a project that could be a complete project unto itself. It takes a specific part of a project such as a central staircase, a specific room or a bell tower and represents it. Sometimes the component model will exist in isolation and sometimes it is built to be inserted into its context.

Chapter 4

Project

Objectives

The operations that we use to model are the fundamental ways that we interact with material. As such they become the base metaphor through which we develop architectural ideas when using models as representation.

This project needed to explore the possibilities of each category of operation. To understand the possibilities of each category of operation it is important to test many variations of fabrication within each operation. Through this we can develop an understanding of how particular operations relate to ideas.

Understanding how multiple operation effect each other within the the same model will be a vital part of this exploration. It will be helpful to understand what operations lend themselves to being used together.

The possibilities of how models can be made are nearly endless. However, by documenting models within this system of operations I can create a resource that can help inform the decision-making process.

To develop a better understanding of how a metaphor emerges from operations of making, I set out to make a series of models following the categories of operation that I established. The models were all made by assembling, framing, layering, carving, shaping and casting. Below are the models made during this investigation.

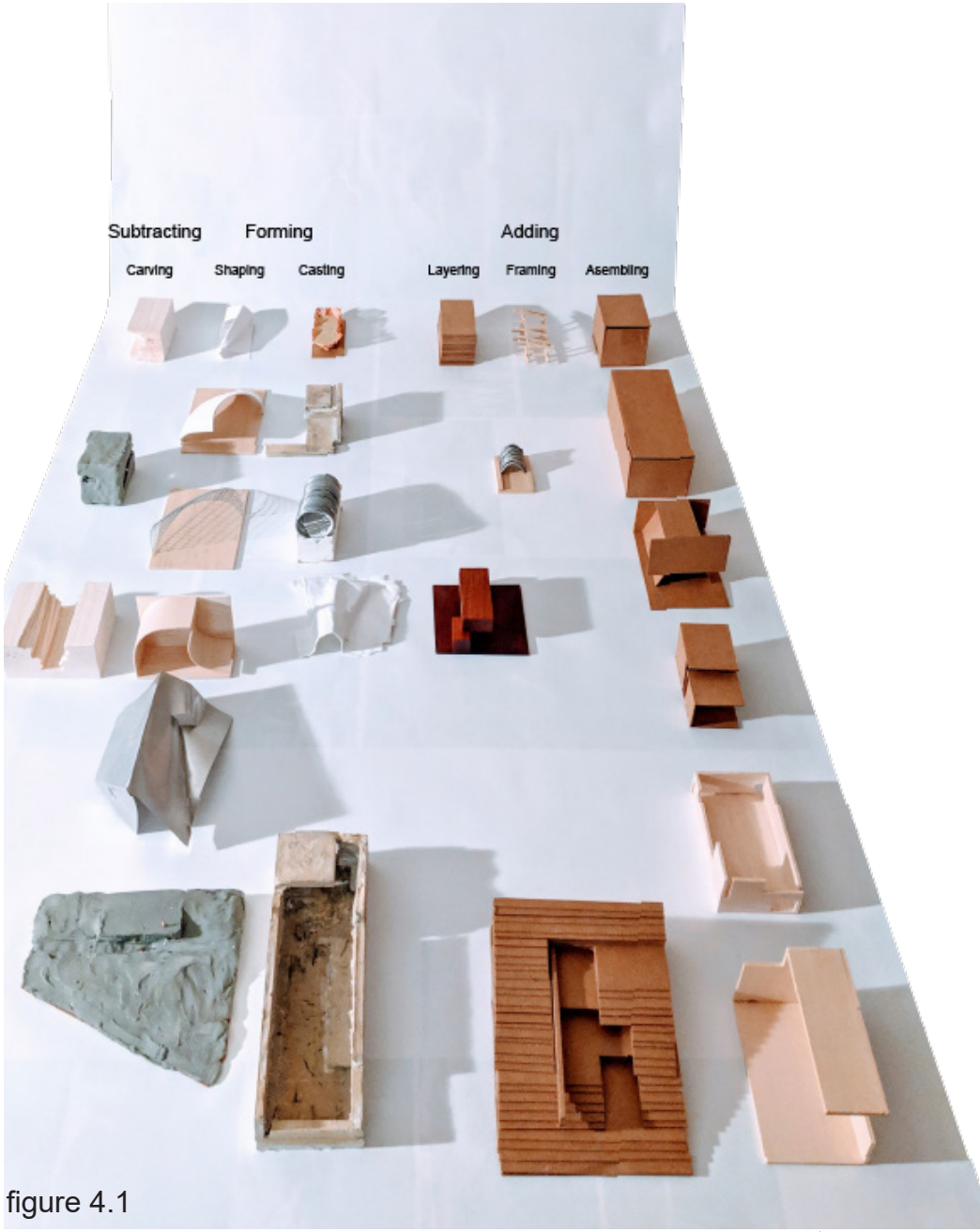


figure 4.1

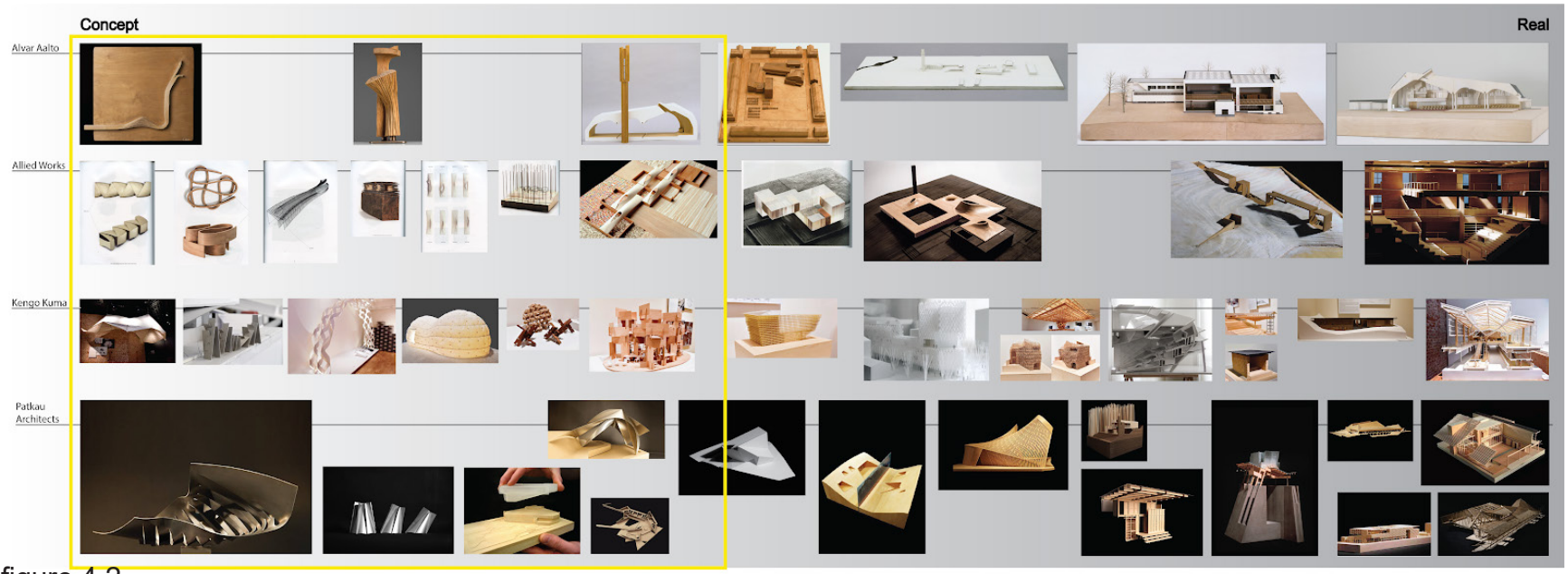
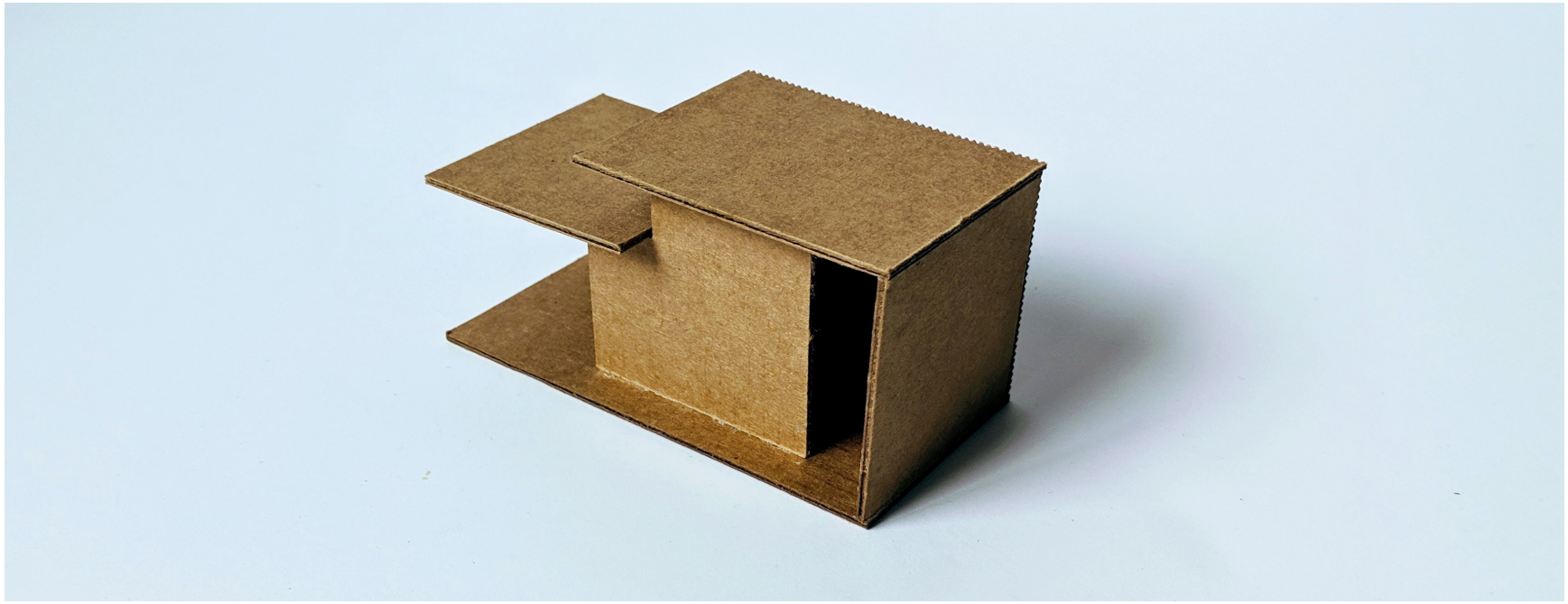

Concept
Real
Alvar Aalto
Allied Works
Kengo Kuma
Patkau Architects

figure 4.2



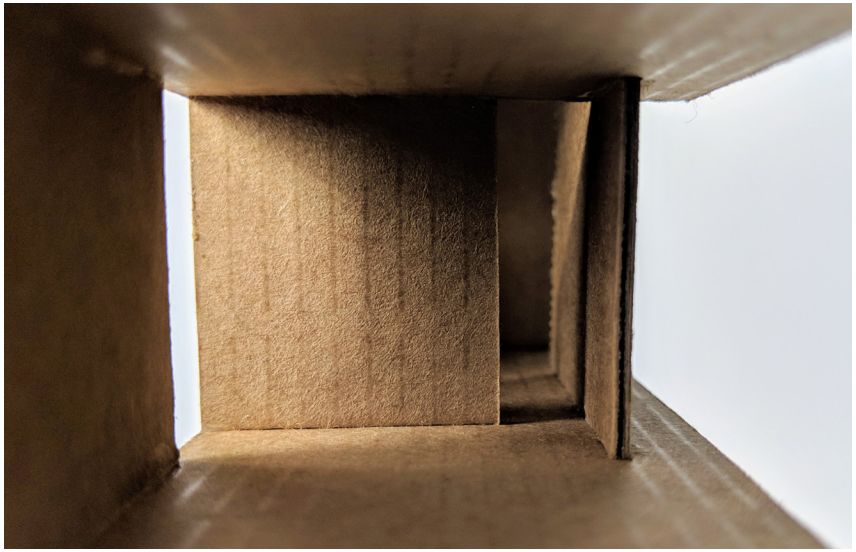
Adding

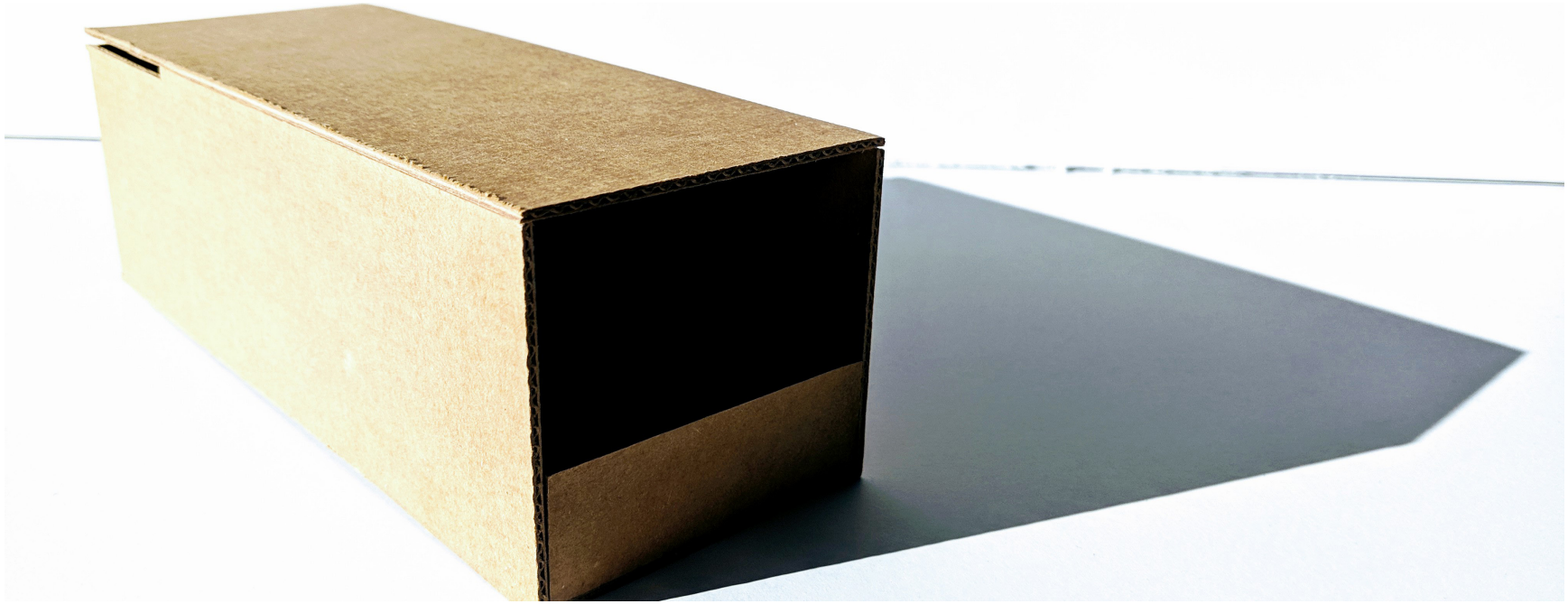
Adding

Assembling

Material: Cardboard e-flute

Intent: The intent of this model was to create several interlocking spaces using intersecting planes.



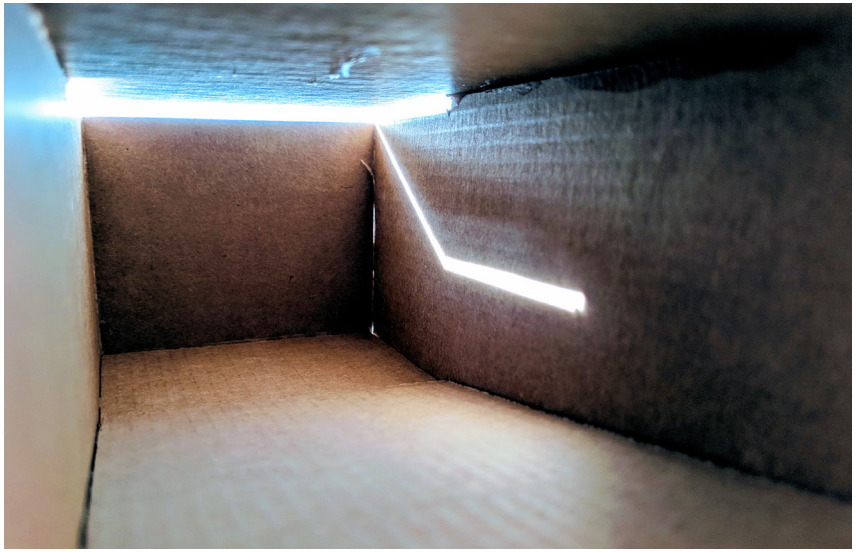


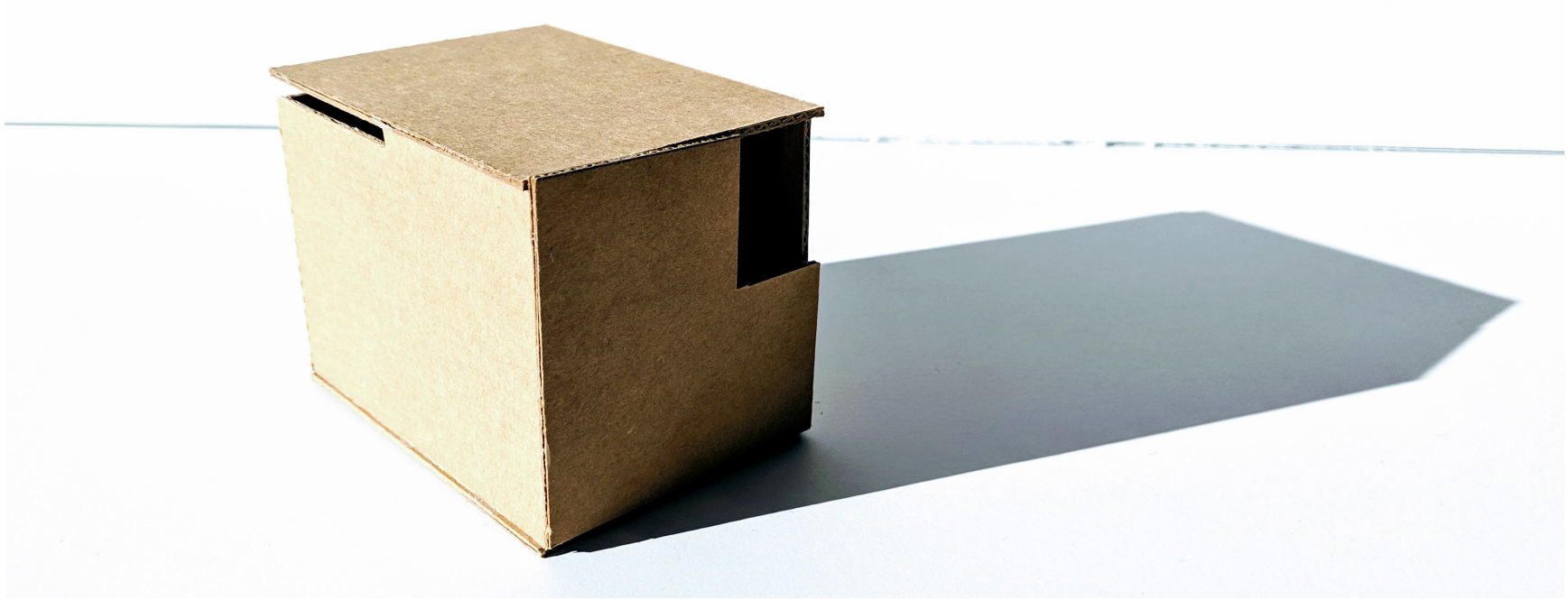
Adding

Assembling

Material: Cardboard e-flute

Intent: The intent of this model was to investigate the use of light to create a sense of heaviness.



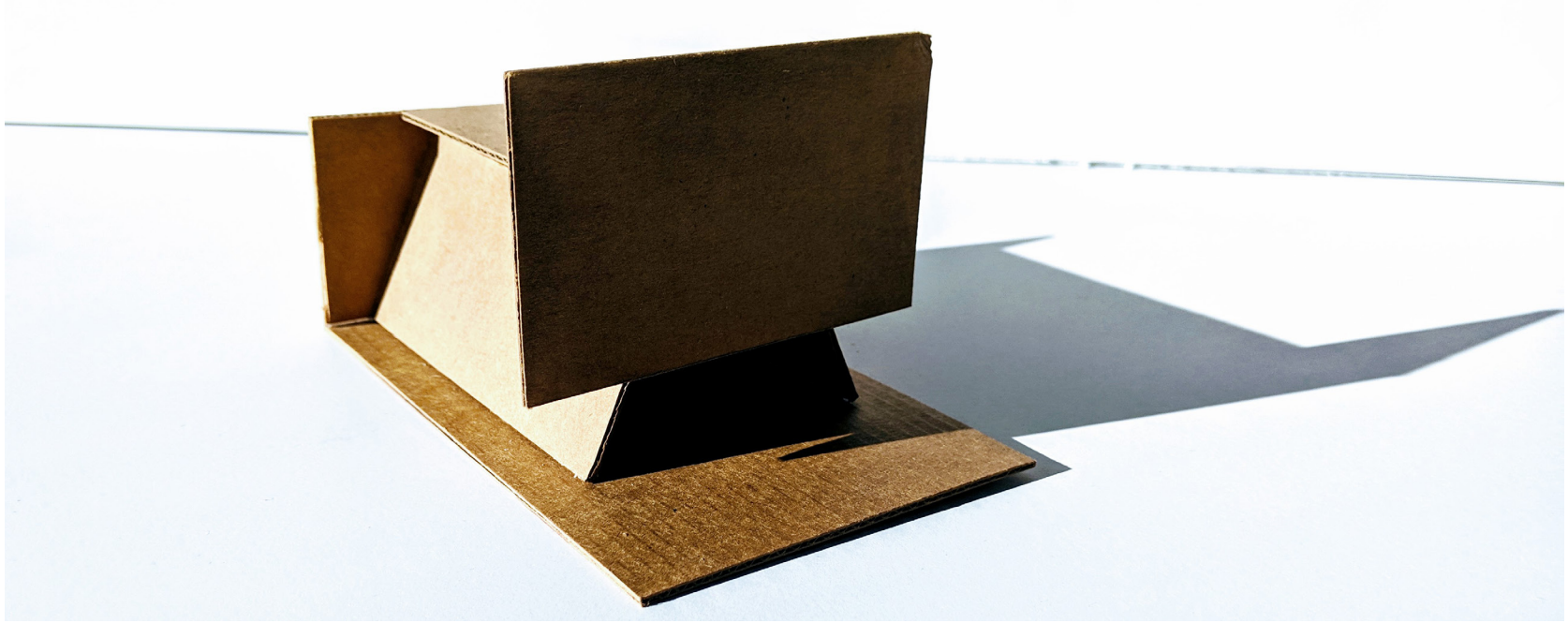


Adding

Assembling

Material: Cardboard e-flute

Intent: The intent of this model was to investigate the use of light to create a sense of heaviness.

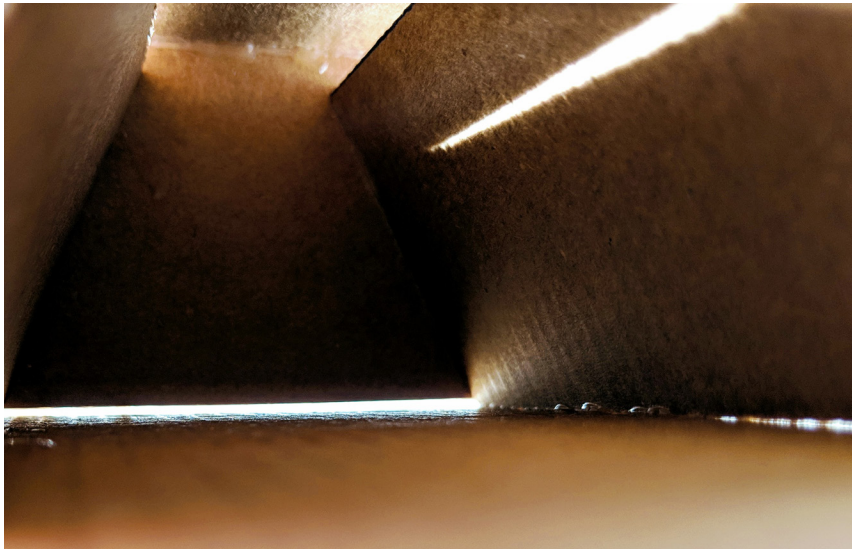


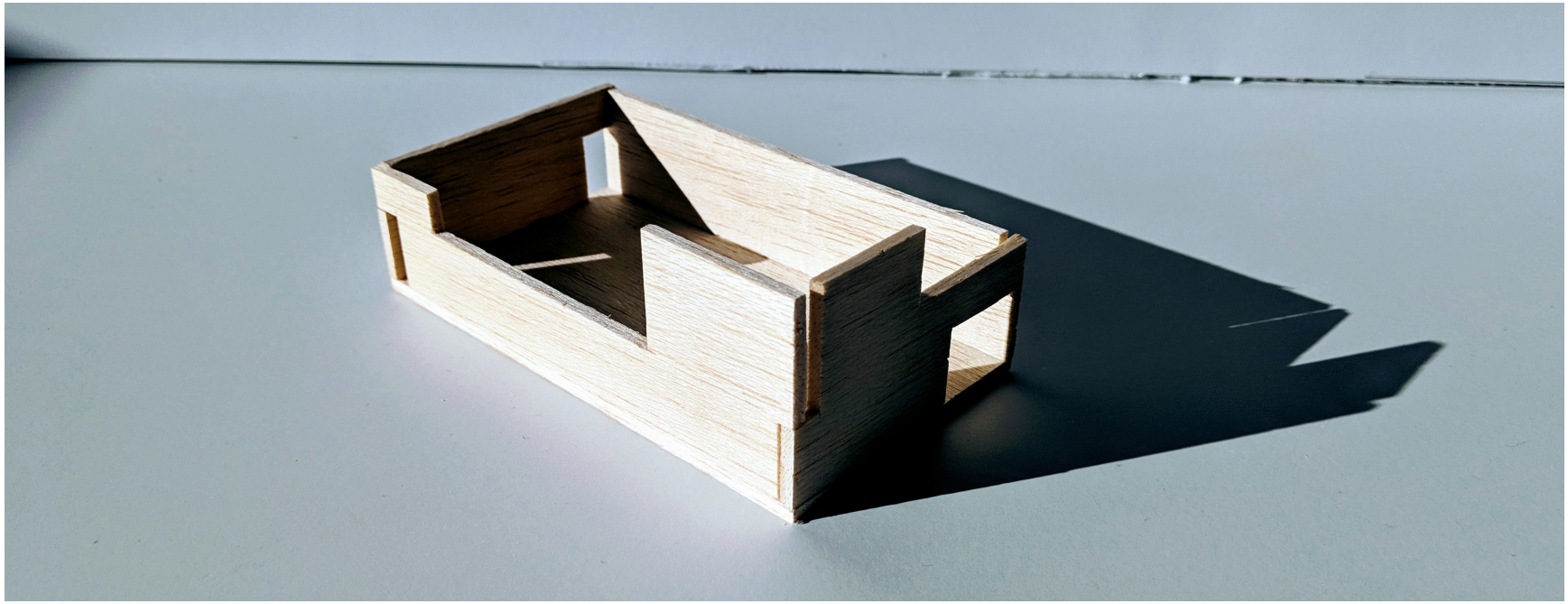
Adding

Assembling

Material: Balsa Wood

Intent: The intent of this model was to explore the creation of apertures at the joints of intersecting planes.



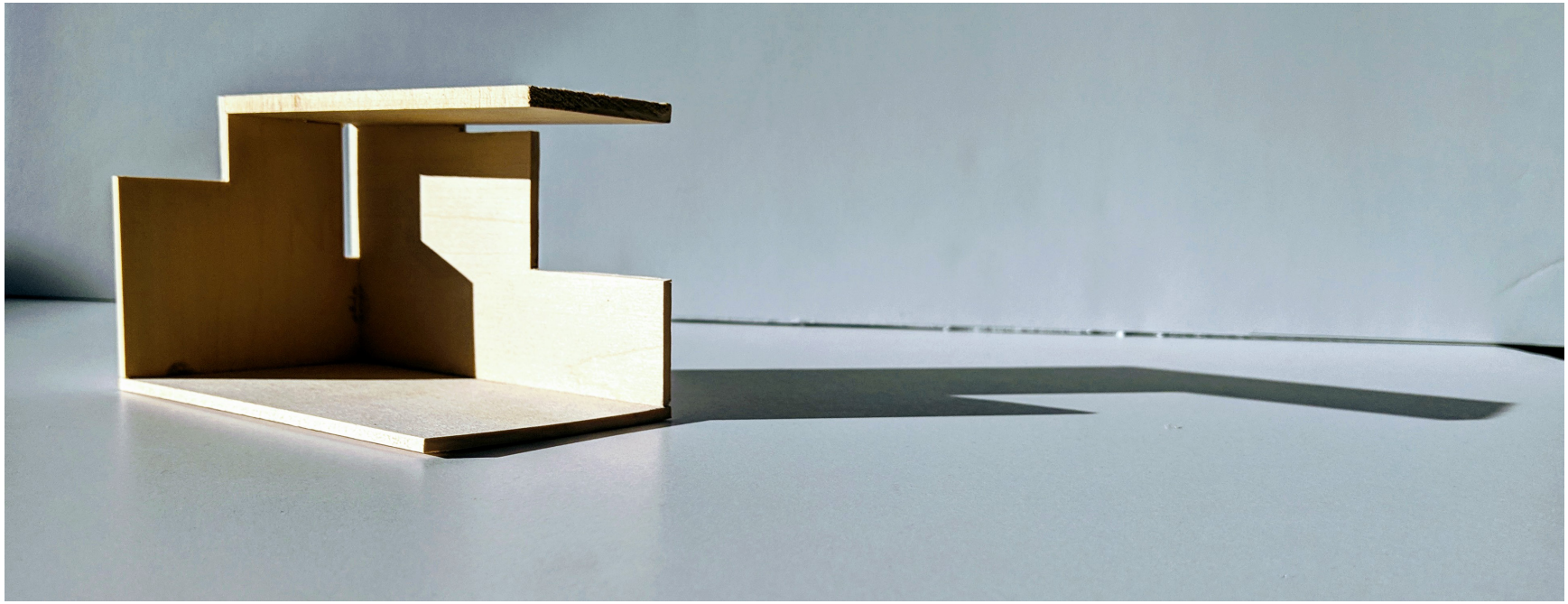


Adding

Assembling

Material: Balsa Wood

Intent: The intent of this model was to explore the creation of apertures at the joints of intersecting planes.

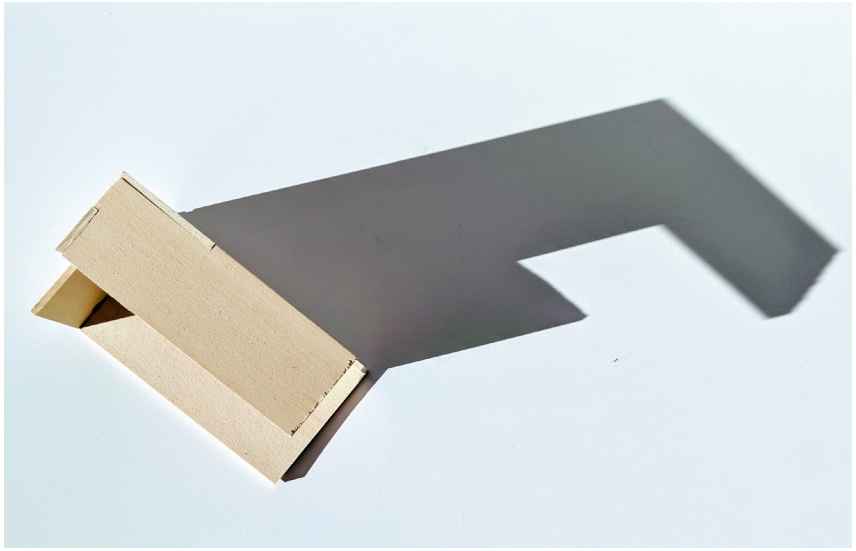


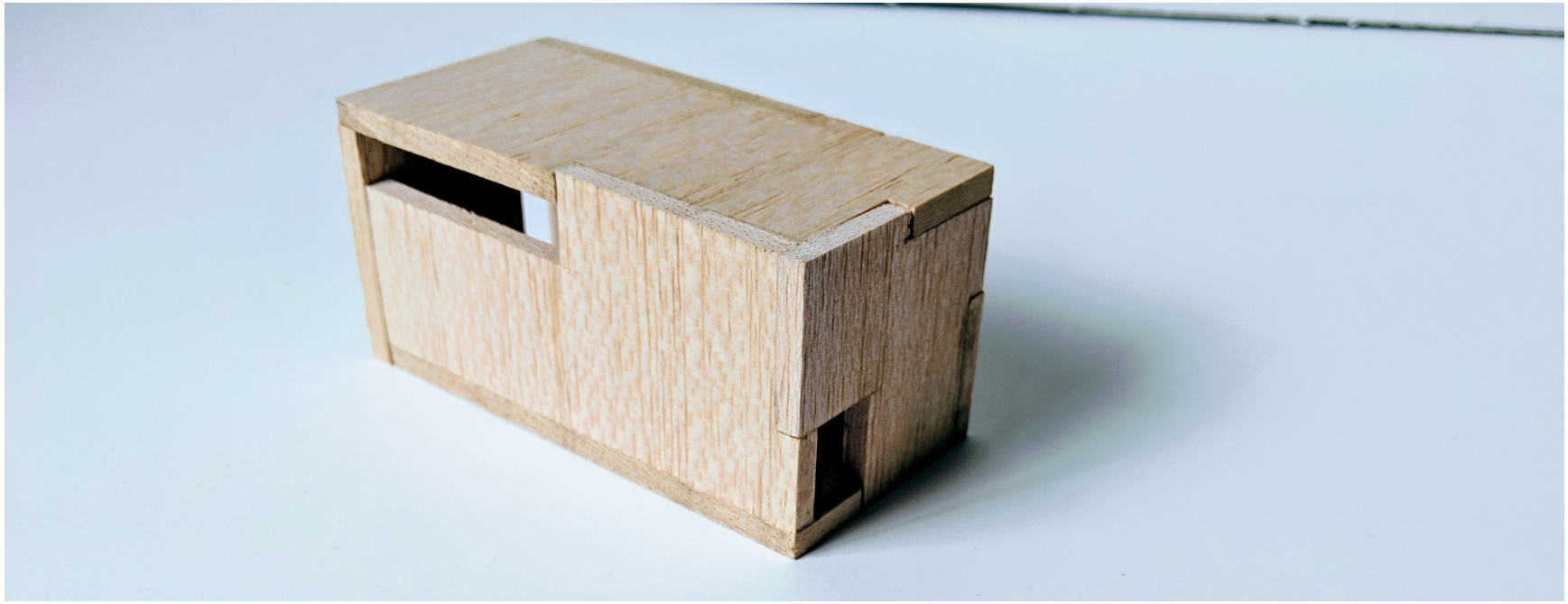
Adding

Assembling

Material: Basswood

Intent: The intent of this model was to explore the creation of apertures at the joints of intersecting planes.





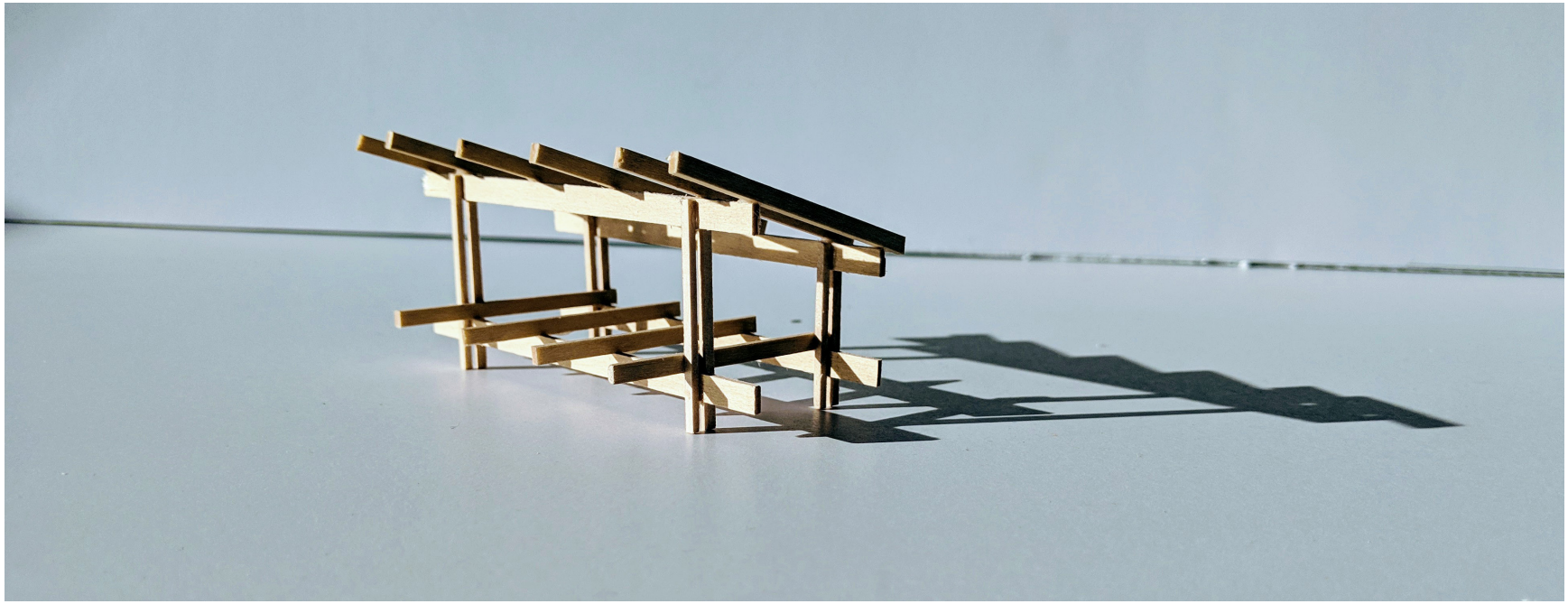
Adding

Assembling

Material: Basswood

Intent: The intent of this model was to explore the creation of apertures at the joints of intersecting planes.

Verbs: to lift, to slide, to join

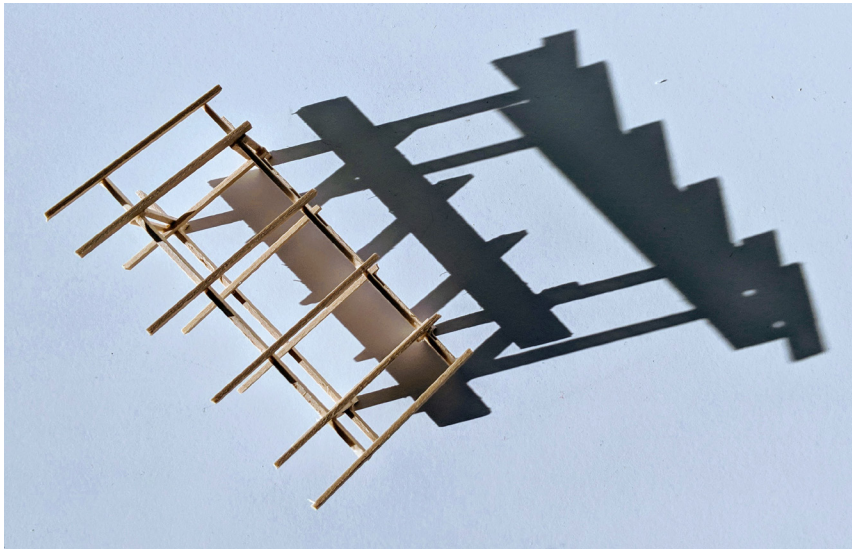


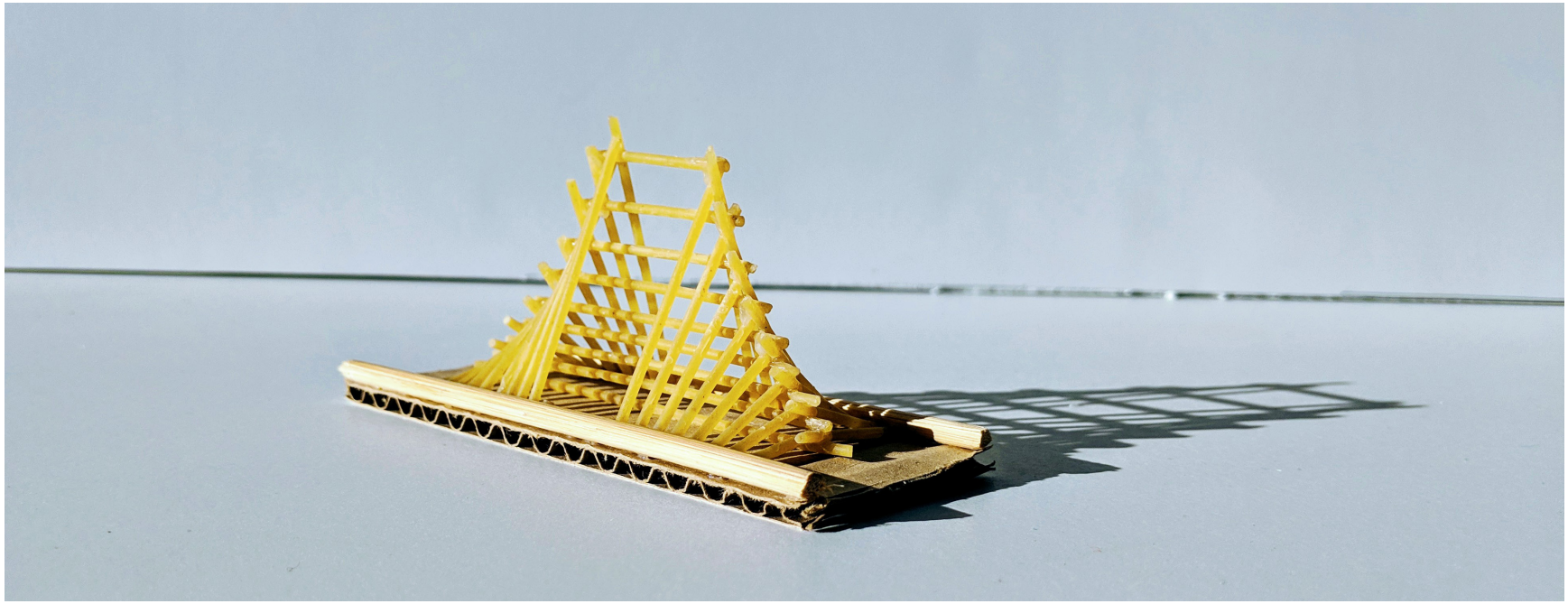
Adding

Framing

Material: Basswood

Intent: The intent of this model was to explore the character of an archetypal framing system.



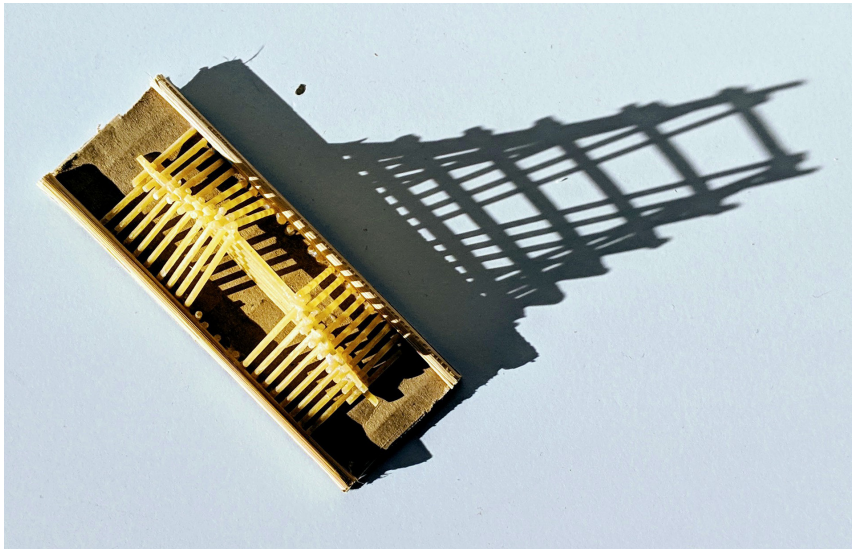


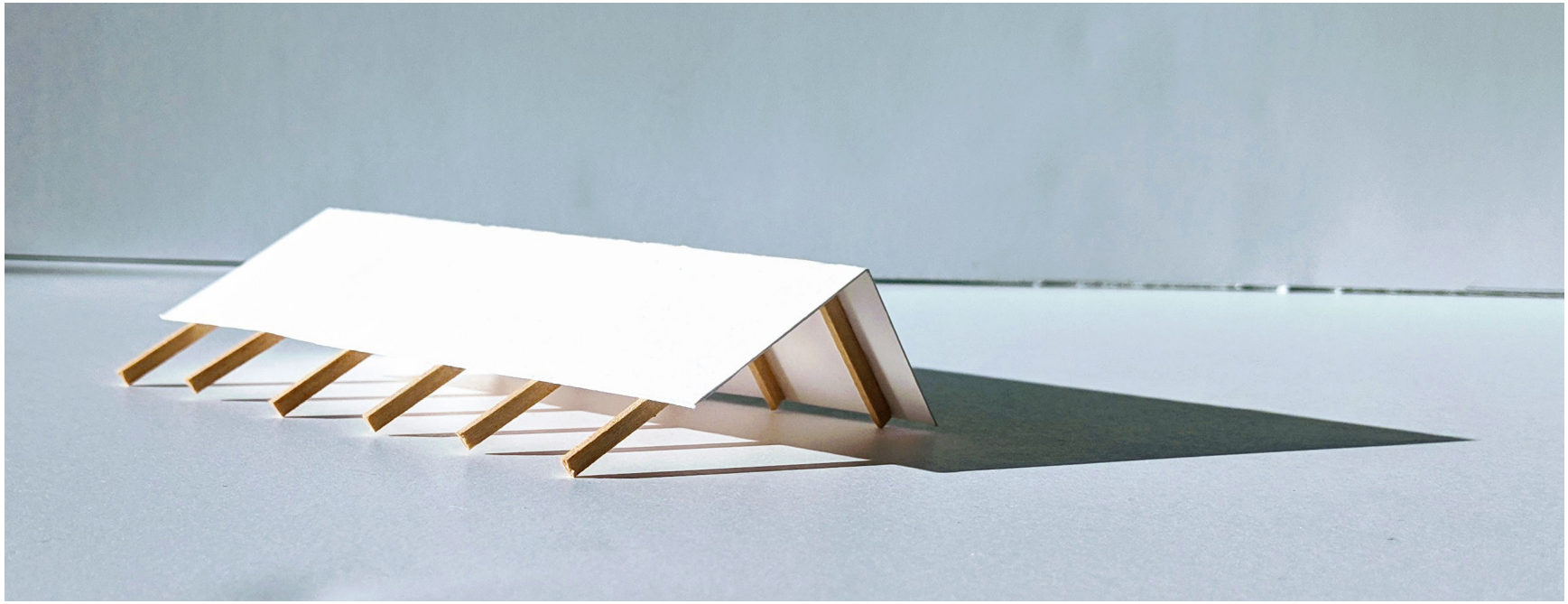
Adding

Framing

Material: Spaghetti noodles

Intent: The intent of this model is to explore exponential growth in a frame. There is an exponential growth in the spacing of the horizontal members.



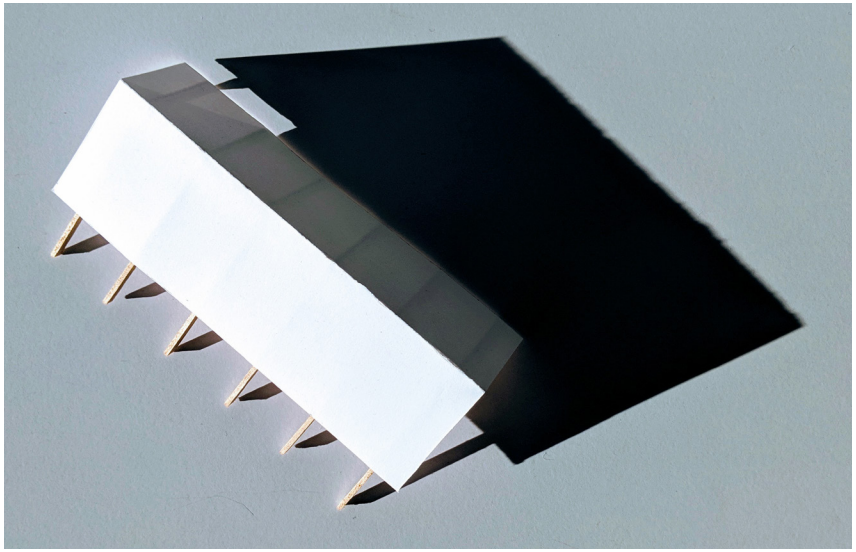


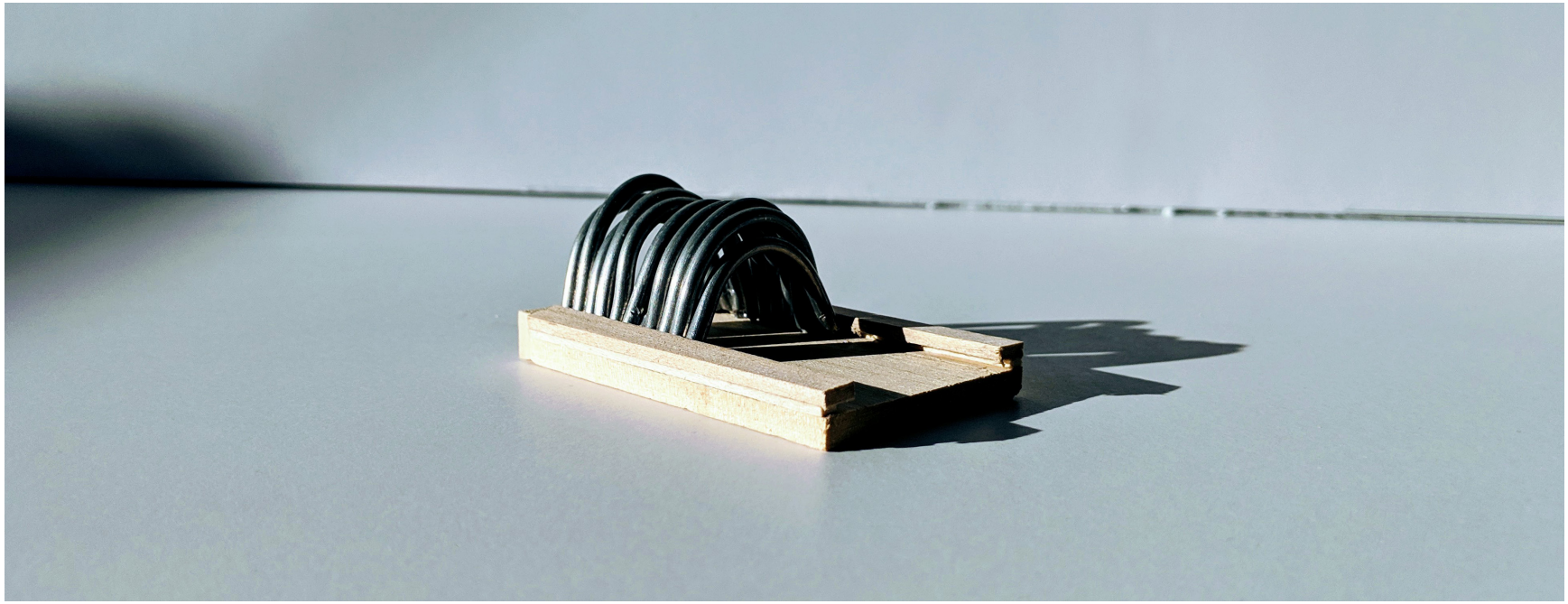
Adding

Framing

Material: Basswood, Bristol board

Intent: The intent of this model was to investigate highway simple framing system can inform an enclosure.





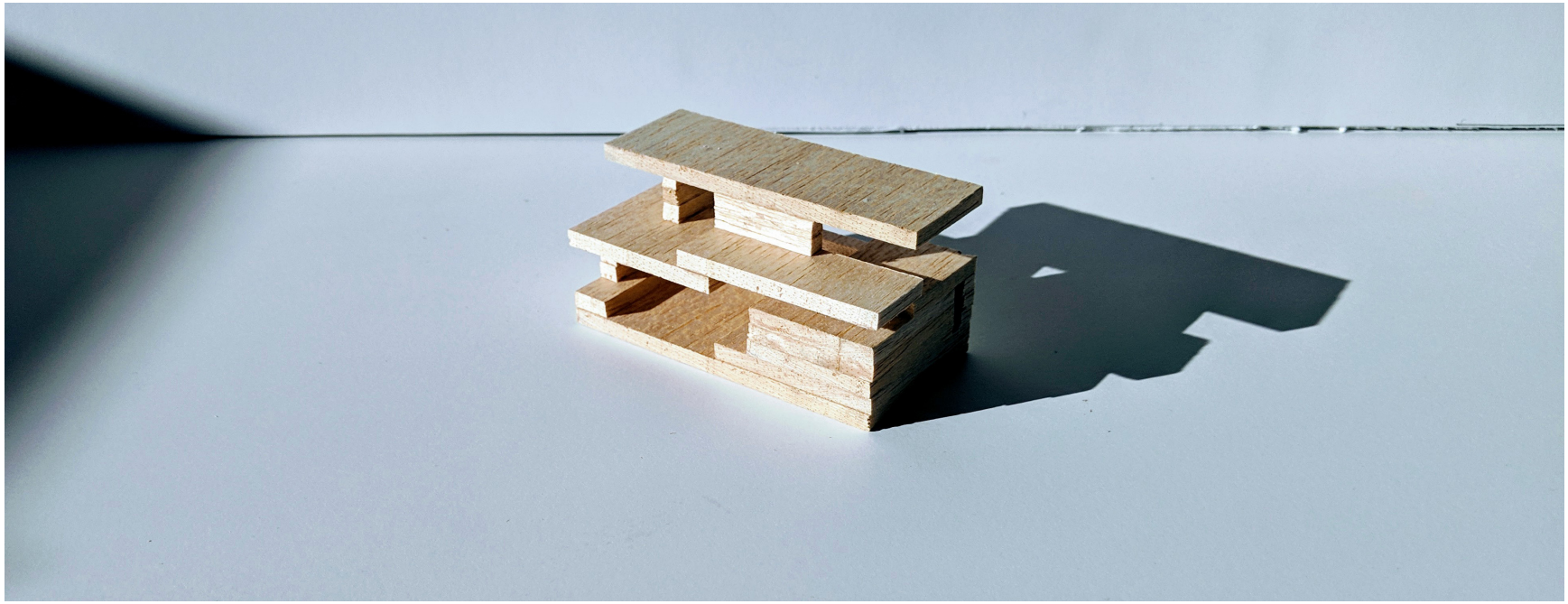
Adding

Framing

Material: Basswood, aluminum wire

Intent: The intent of this model was to look at a slightly irregular frames and explore where the framing approaches the layer.

Verbs: to cage,

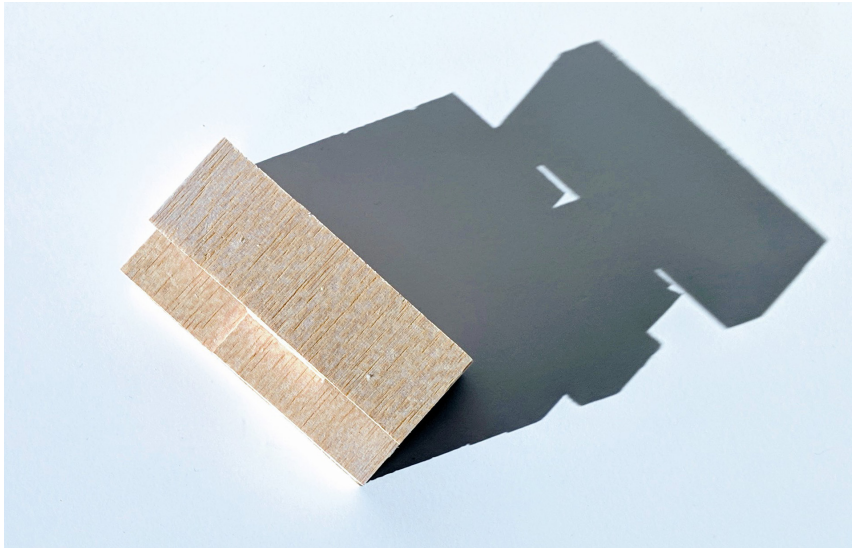


Adding

Layering

Material: Balsa Wood

Intent: The intent of this model was to demonstrate the layering operation.

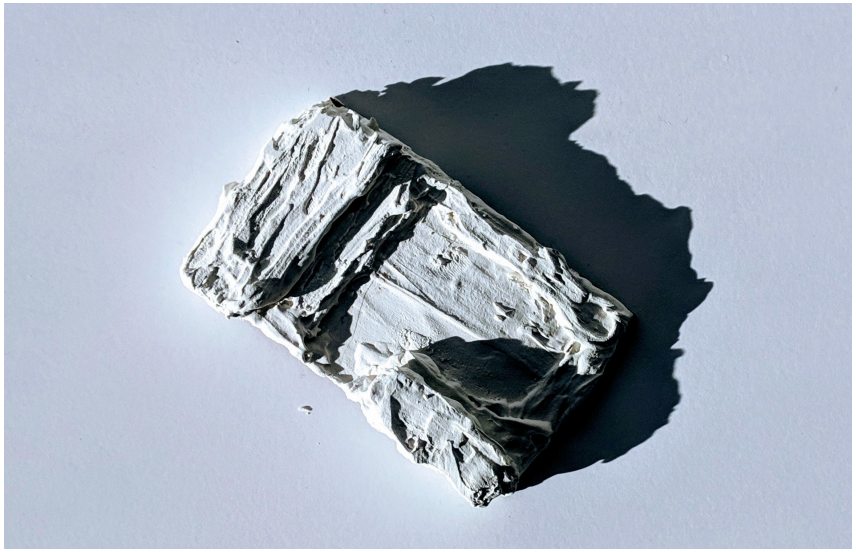


Adding

Layering

Material: Drywall mud

Intent: The intent of this model was to explore layering as an expression of time. The layers of mud were painted on and then allowed to dry before the next layer could be added.

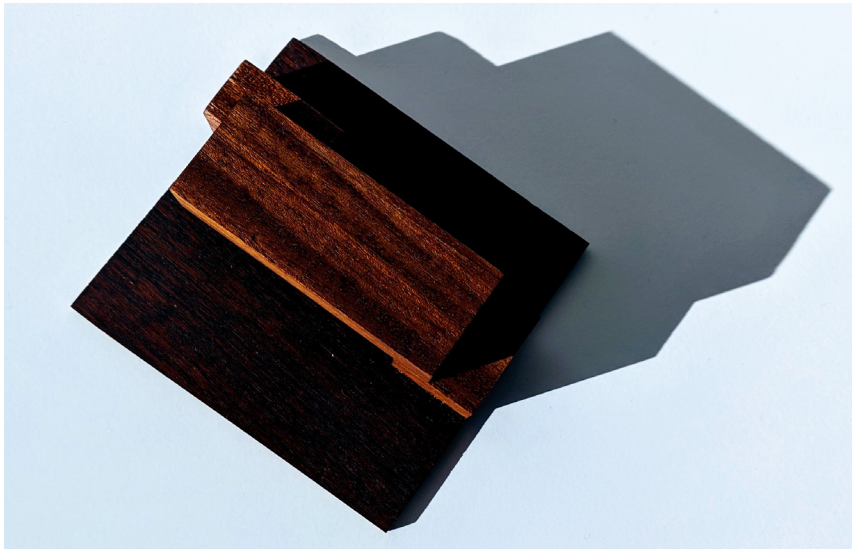


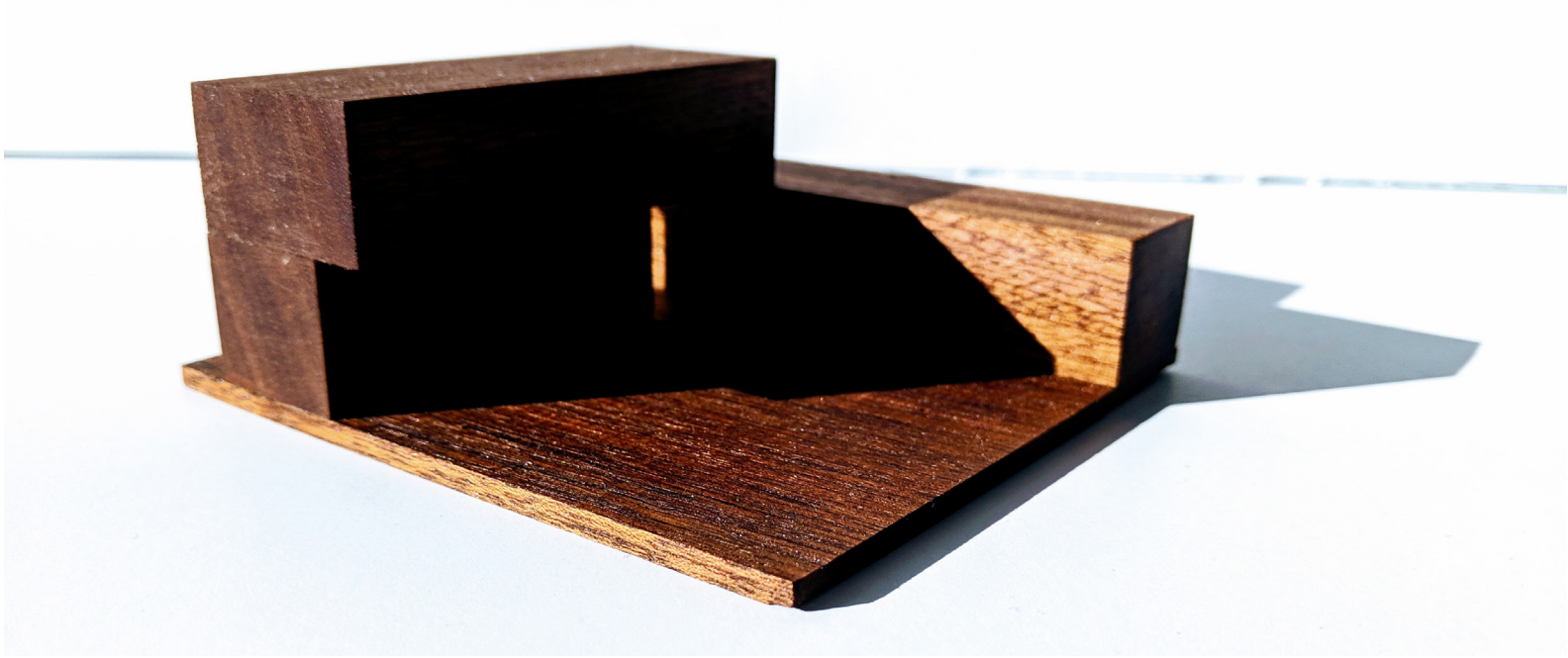
Adding

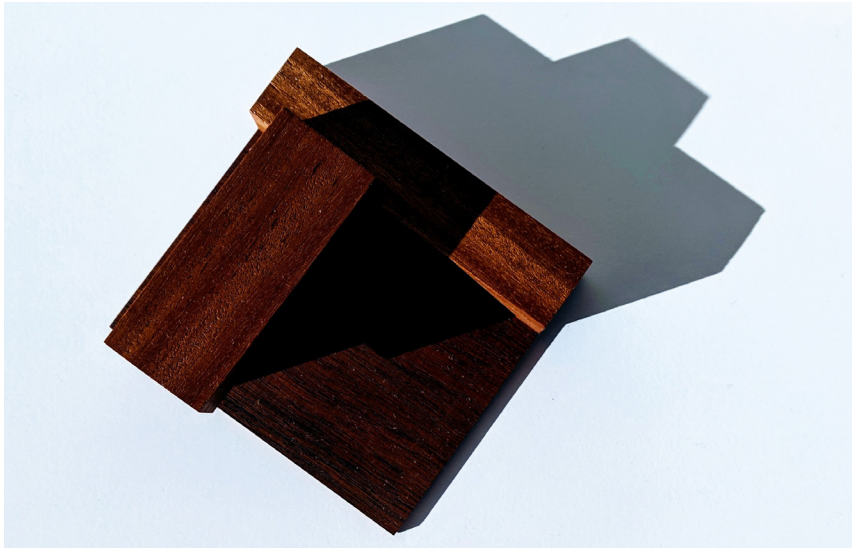
Layering

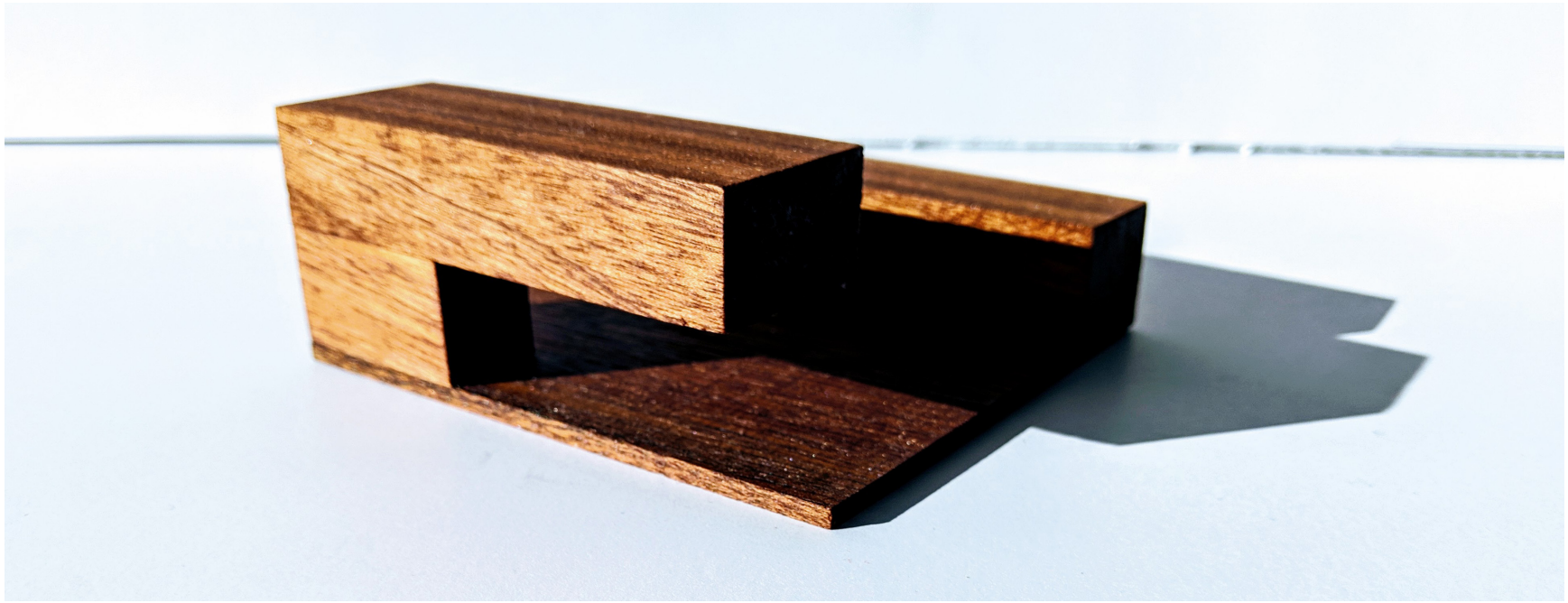
Material: Mahogany

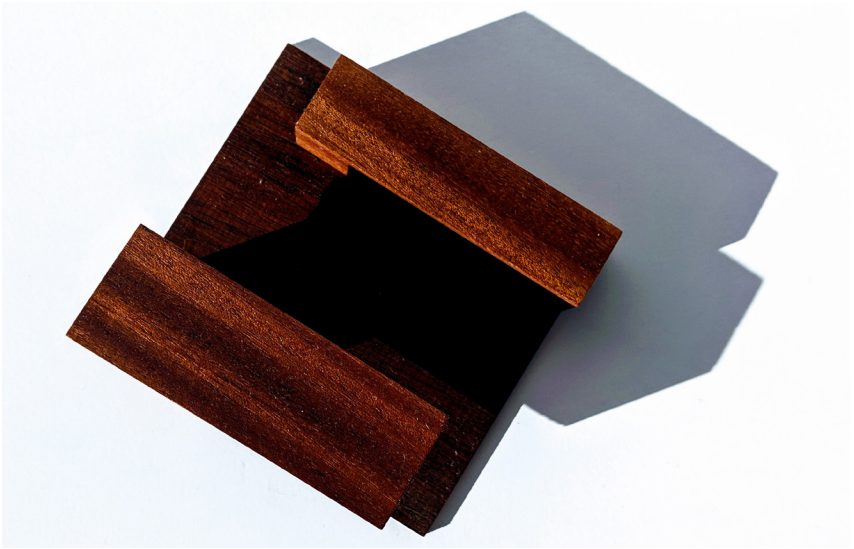
Intent: The intent of these four models was to explore the containment of space through mass.

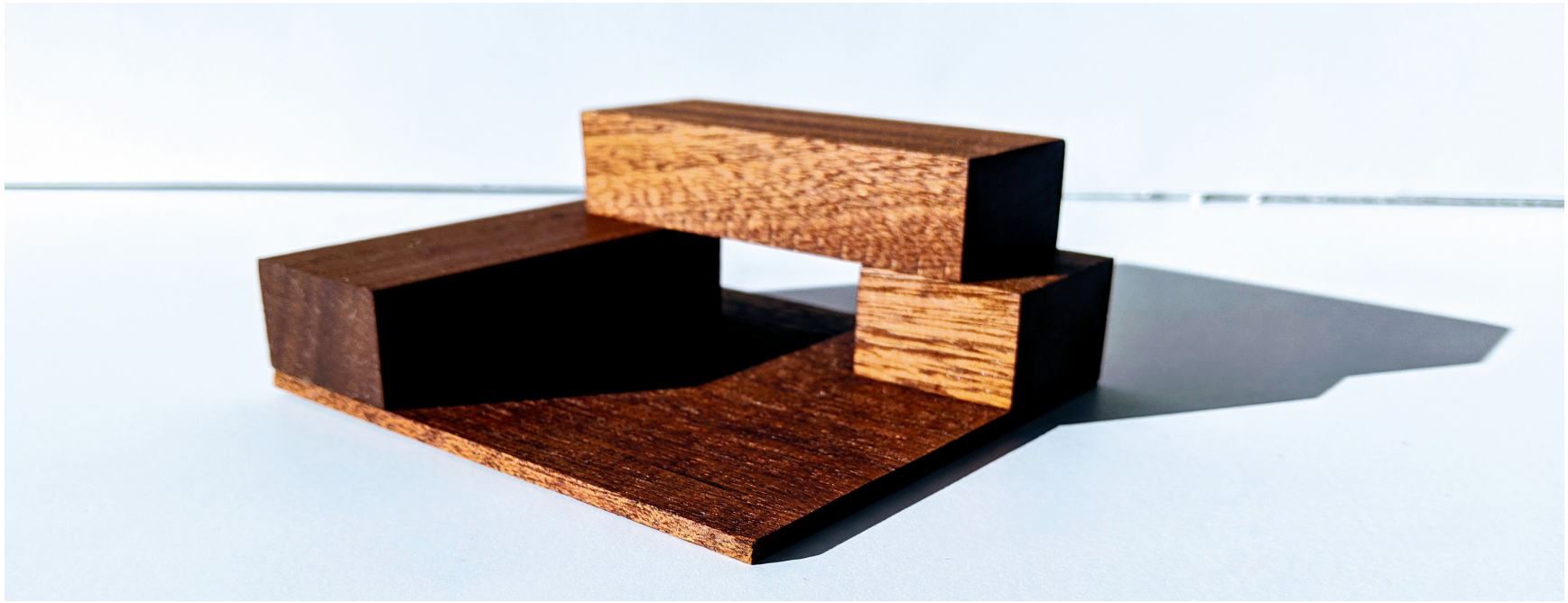


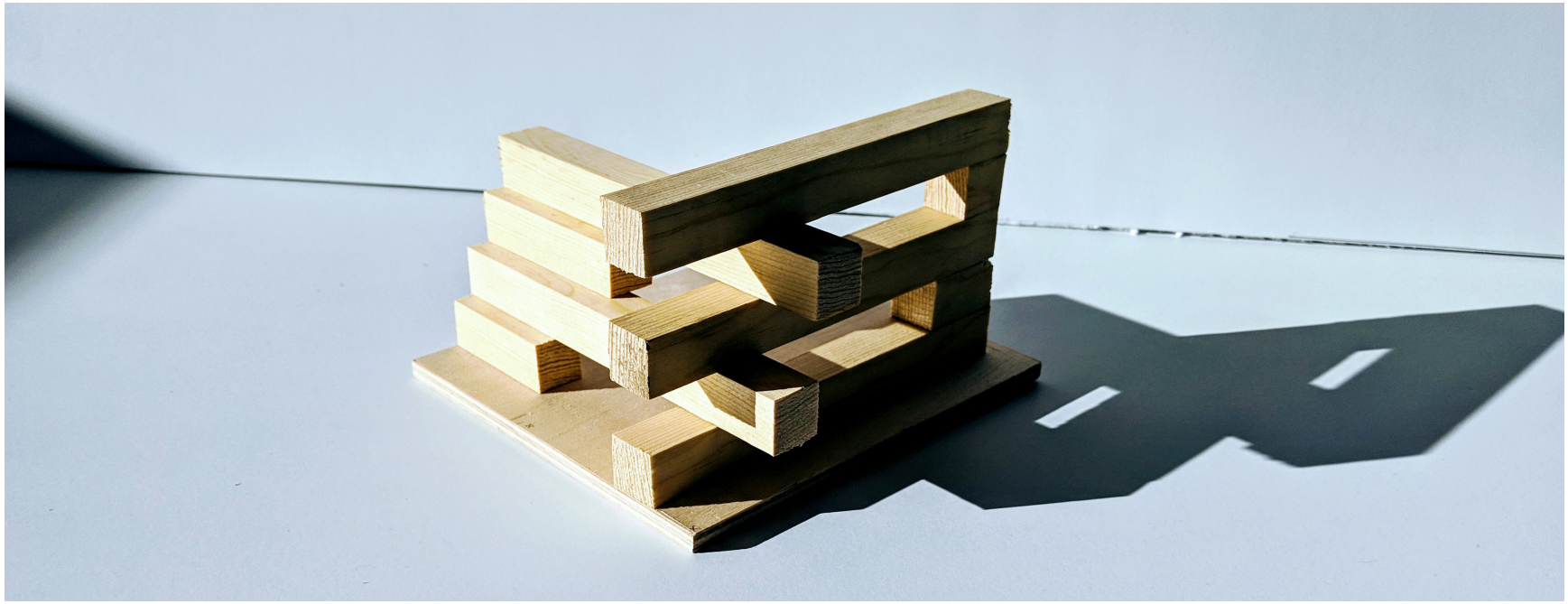










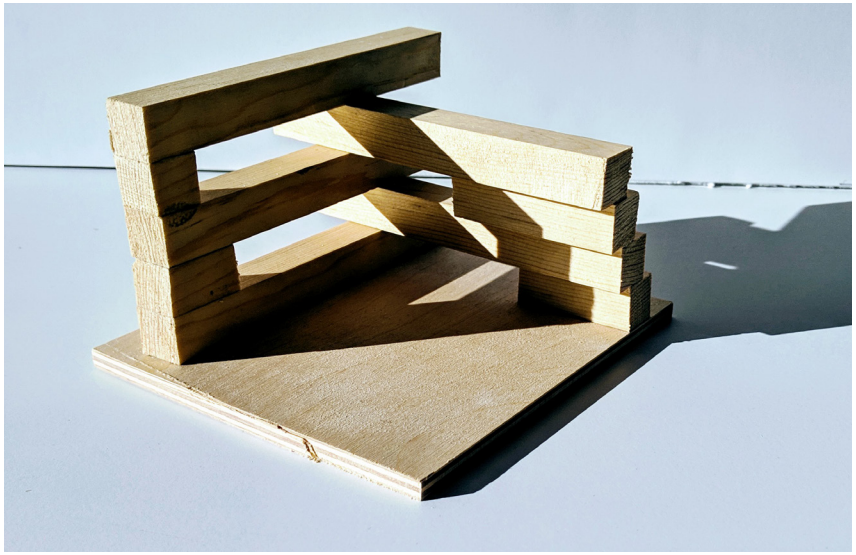


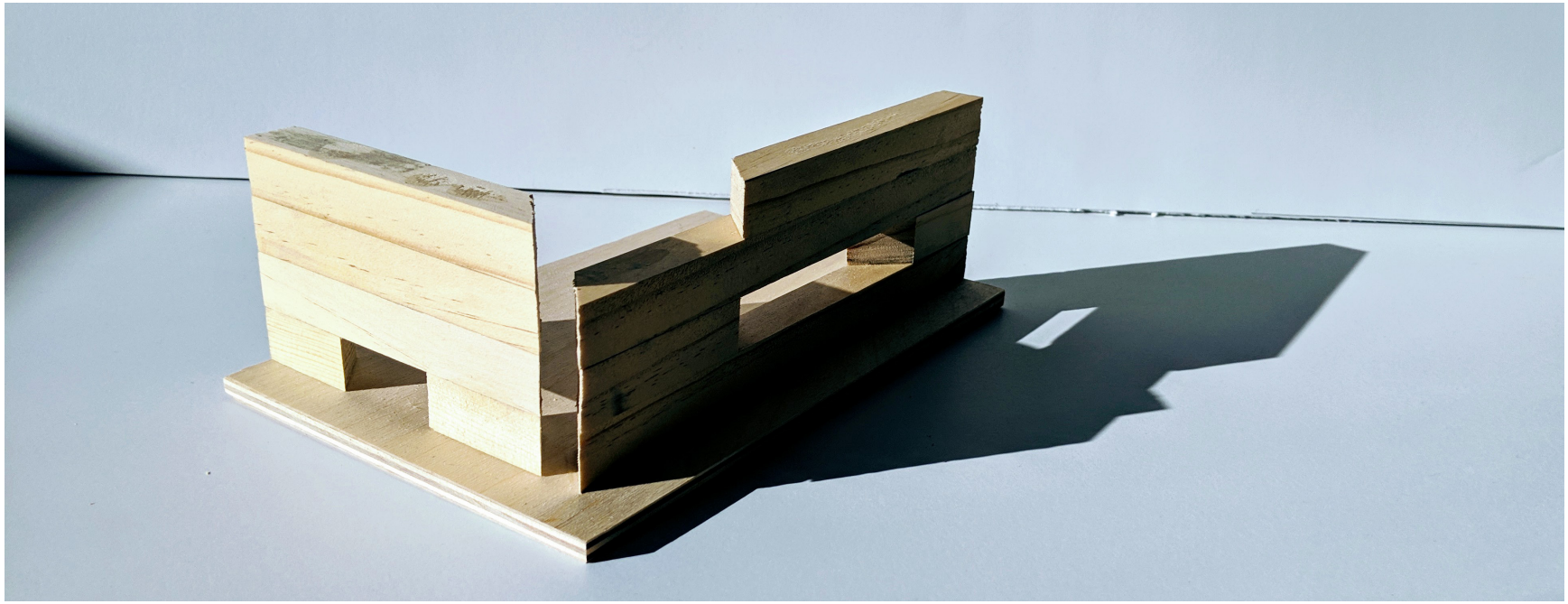
Adding

Layering

Material: Pine wood

Intent: The intent of this model was to explore the character of a layered wall system.



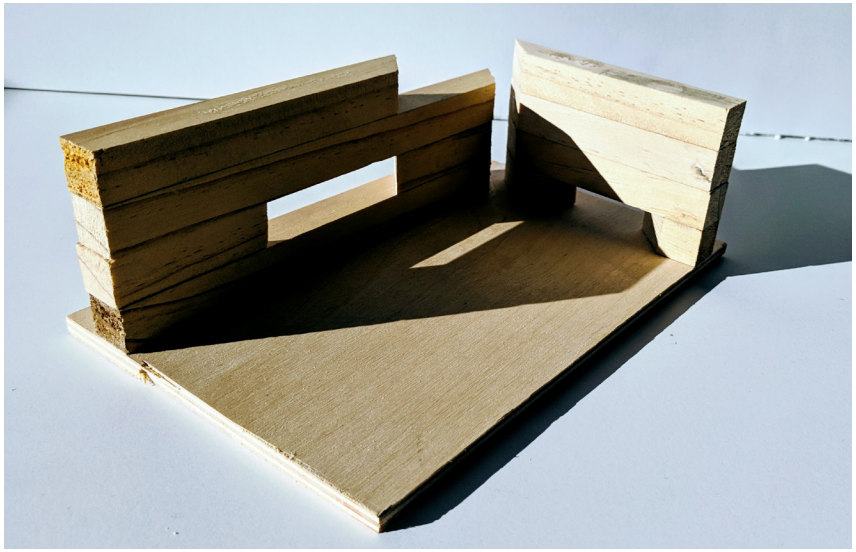


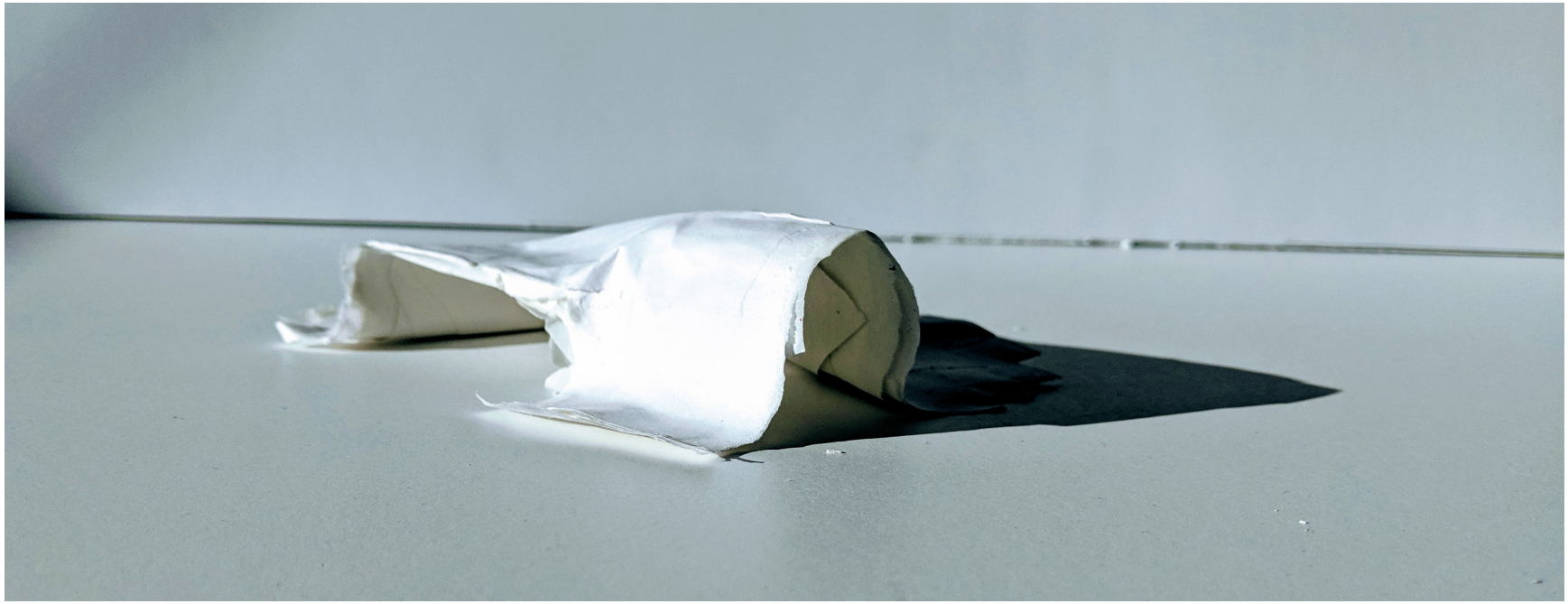
Adding

Layering

Material: Pine wood

Intent: The intent of this model was to continue exploring the character of a layered wall system. In this model the layers are in 45 degree angles. This is meant to explore how the shape of the material being layered might change the character of the wall.



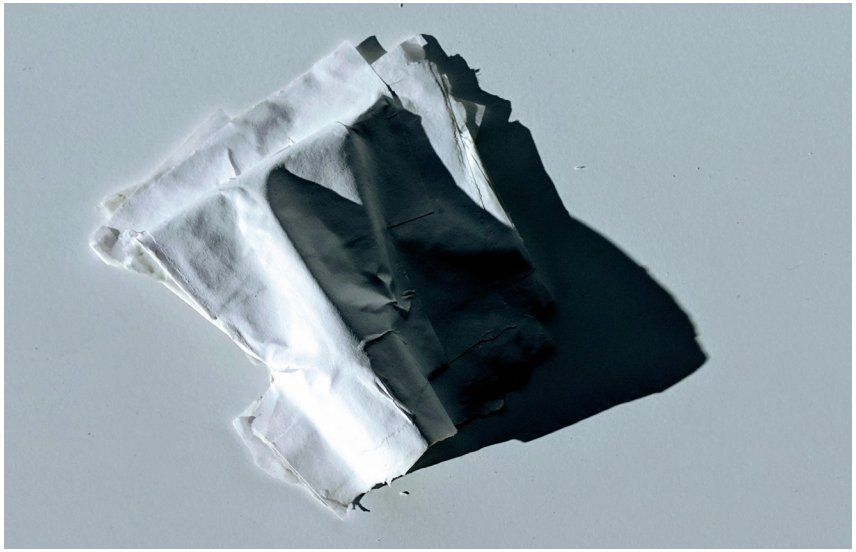


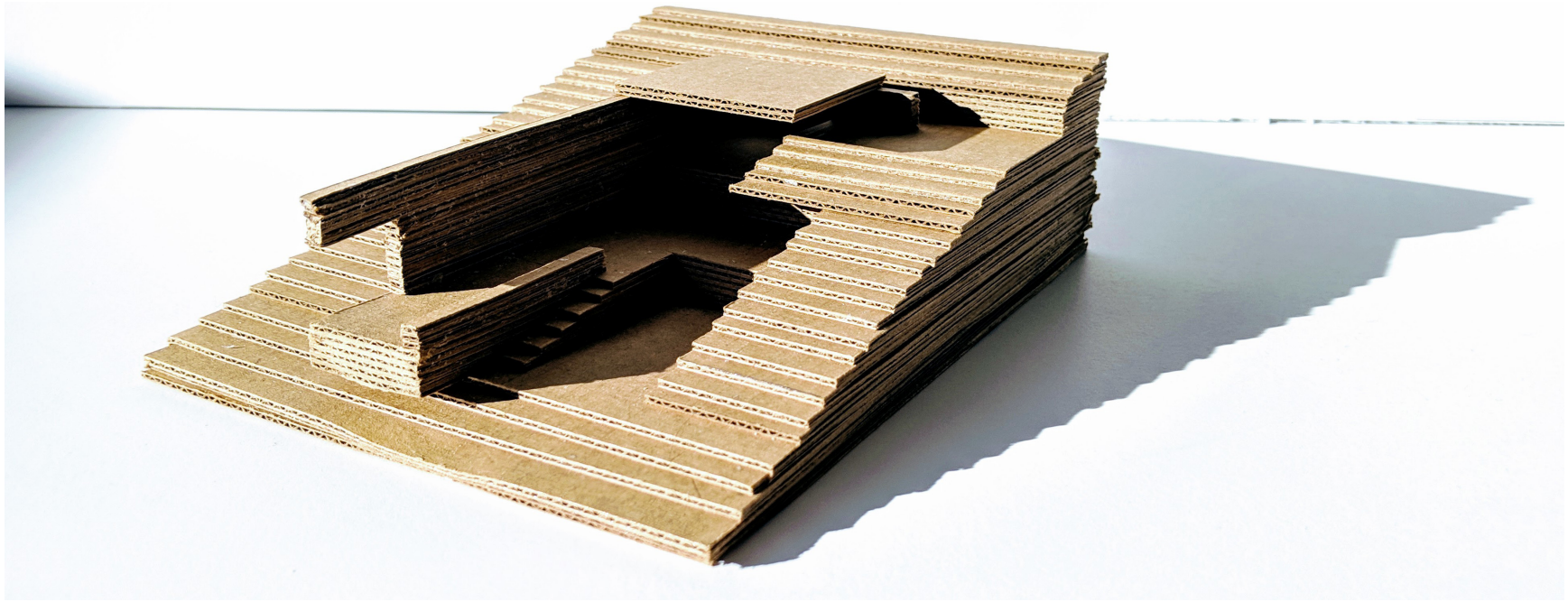
Adding

Layering

Material: Paper mache

Intent: The intent of this model was to explore how the layering operation could be used to make more organic forms. Since the model was created by draping paper mache over a formwork. it has a very strong overlap with forming.





Adding

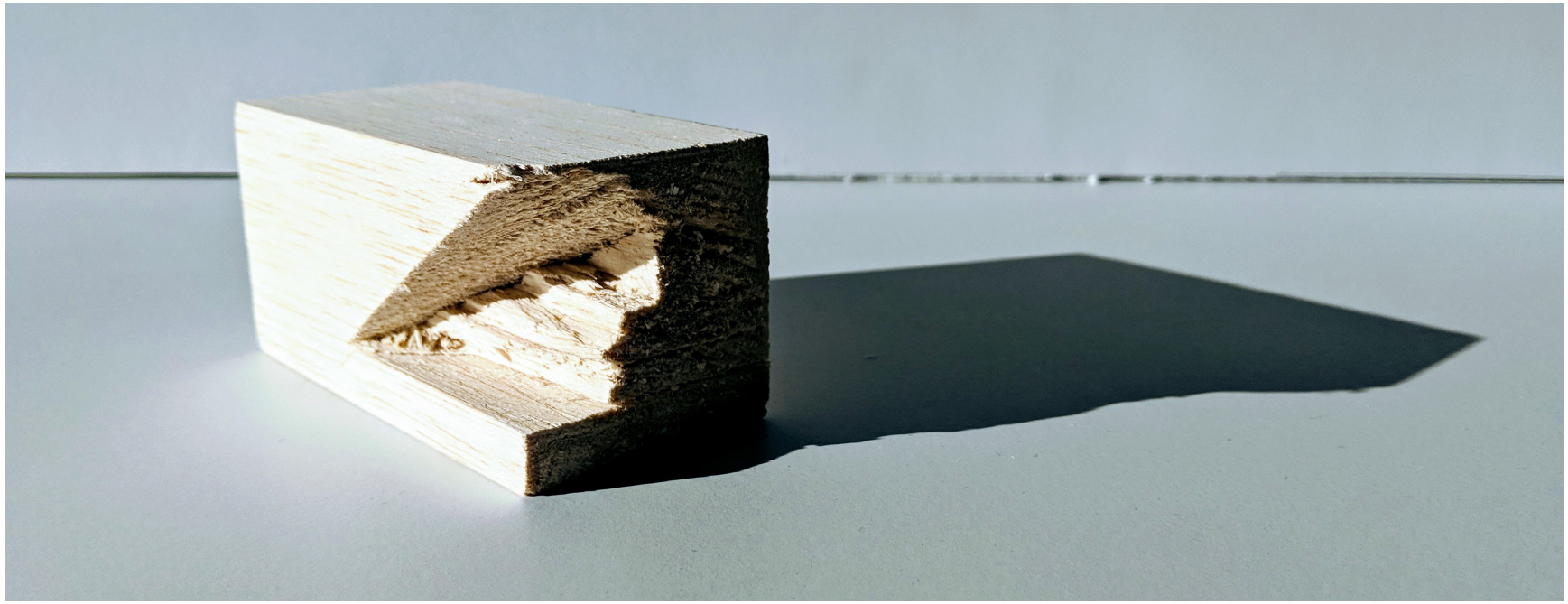
Layering

Material: Cardboard e-flute

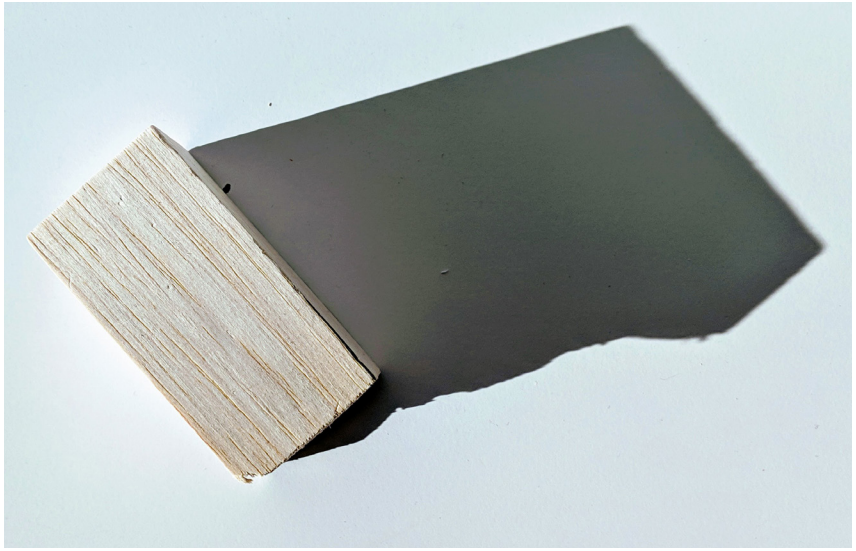
Intent: The intent of this model was to enclose the space that felt as though it were an embodiment of time. Every shift in the model happens at a change of layer.

Although this model was built primarily with the operation of layering it has a strongly subtractive character as well. This comes from the removal of material in The layers that carve out the hillside.

Verbs: to layer, to stack, to slide,



Subtracting

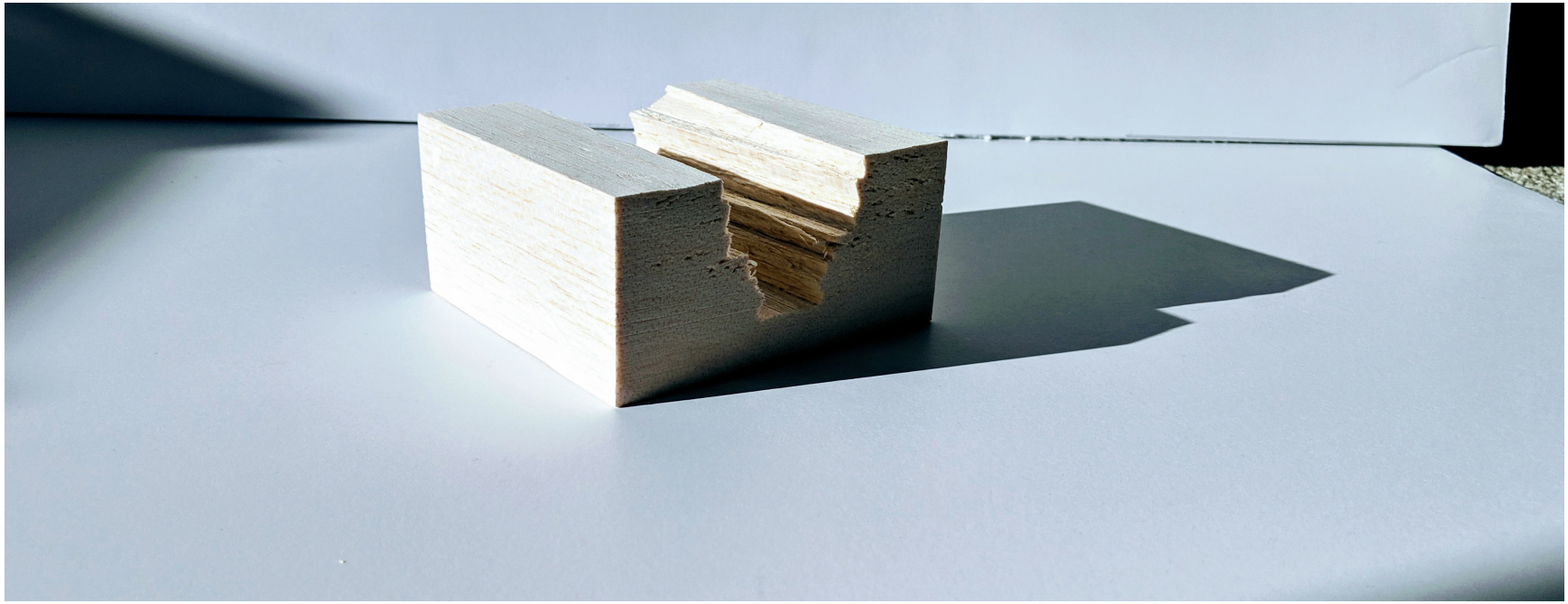


Subtracting

Carving

Material: Balsa Wood

Intent: The intention of this model was to demonstrate the operation of carving through the removal of material from a solid.

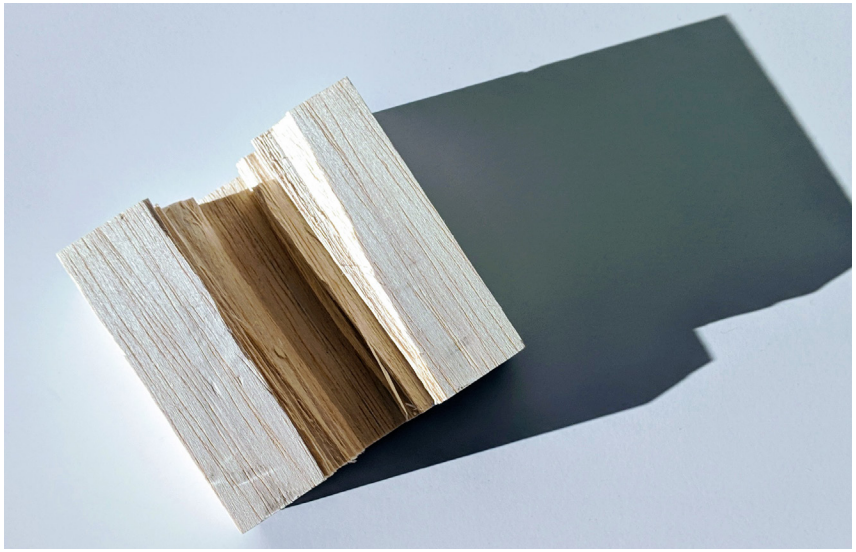


Subtracting

Carving

Material: Balsa wood

Intent: The intent of this model was to create a sense of enclosure. The enclosure was inspired by the idea of a canyon.



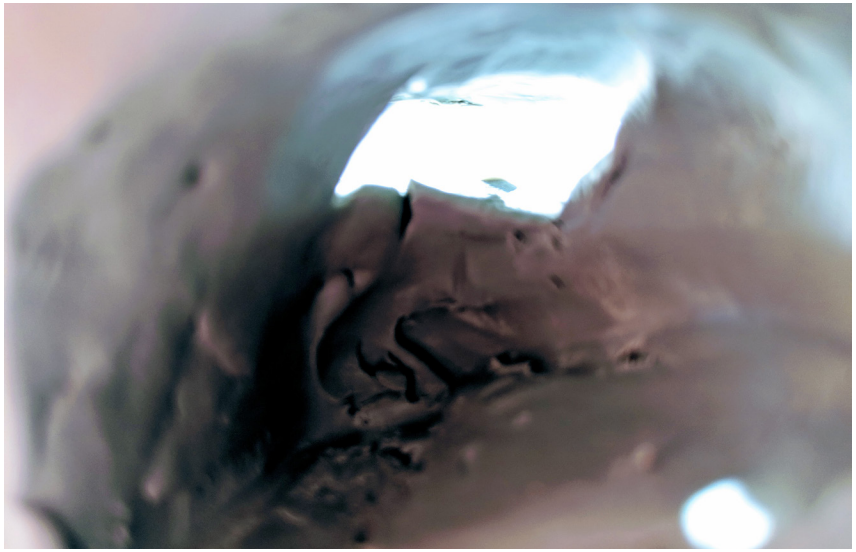
Subtracting

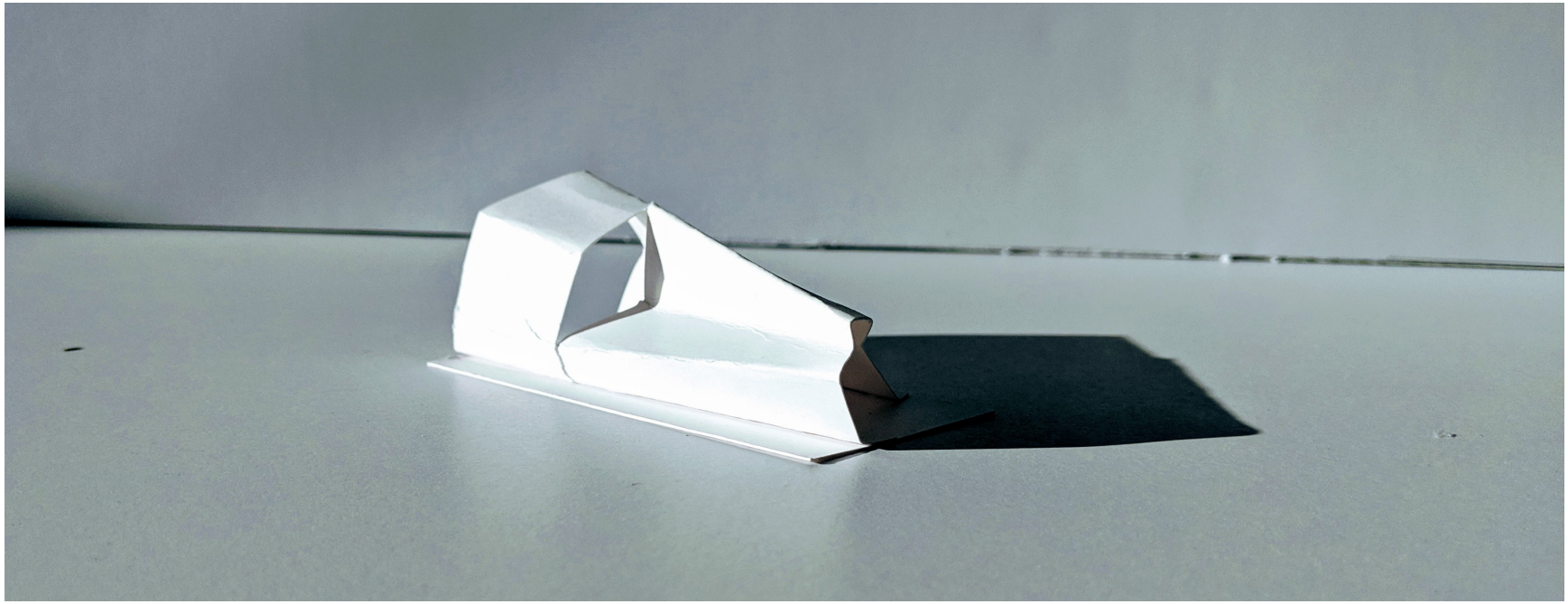
Carving

Material: Plasticine clay

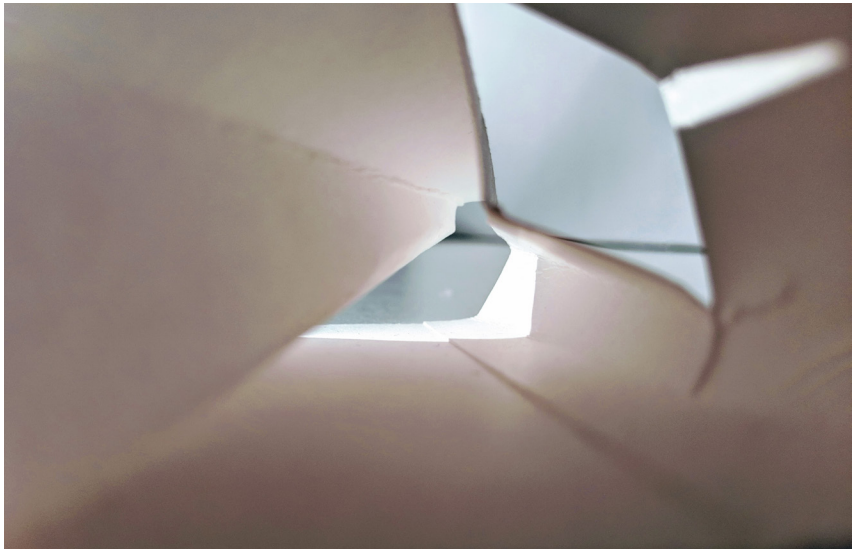
Intent: The intent of this model is to explore a sense of being in a cave.

Verbs: to carve, to dig, to tunnel, to burrow, to scrape





Forming

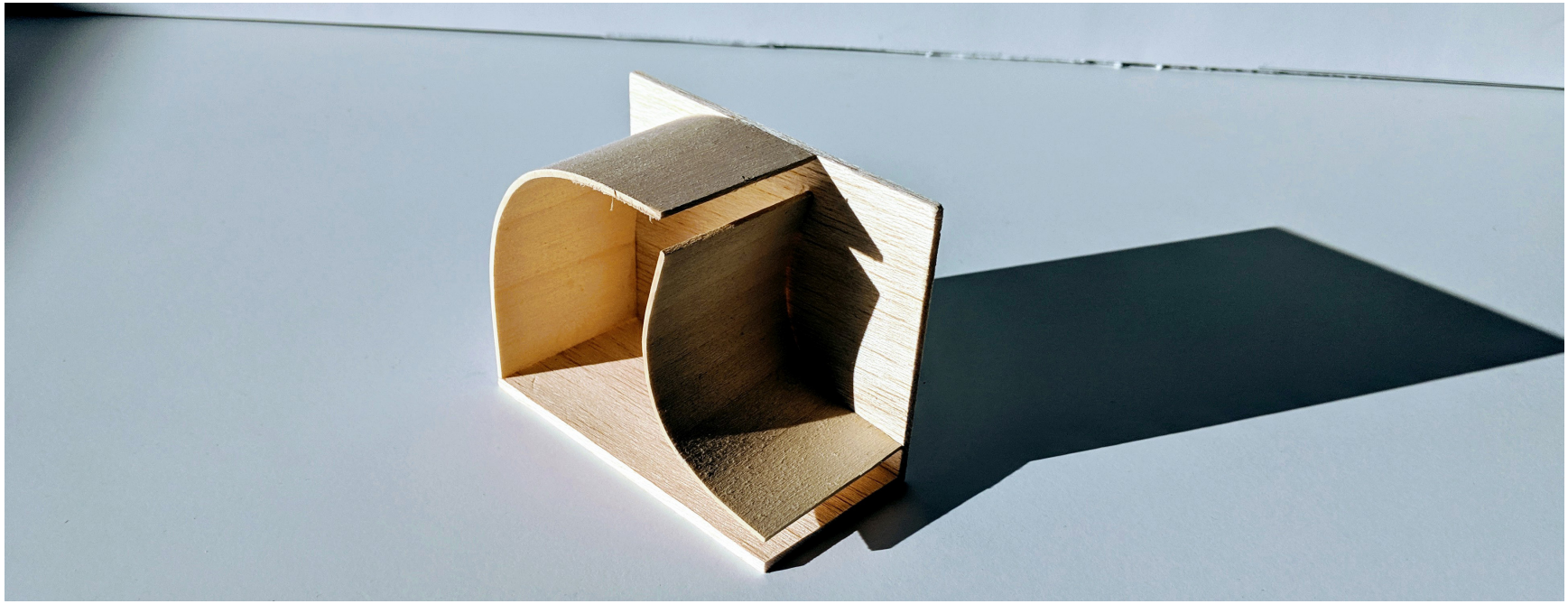


Forming

Shaping

Material: Bristol board

Intent: The intent of this model was to demonstrate the operation of shaping.

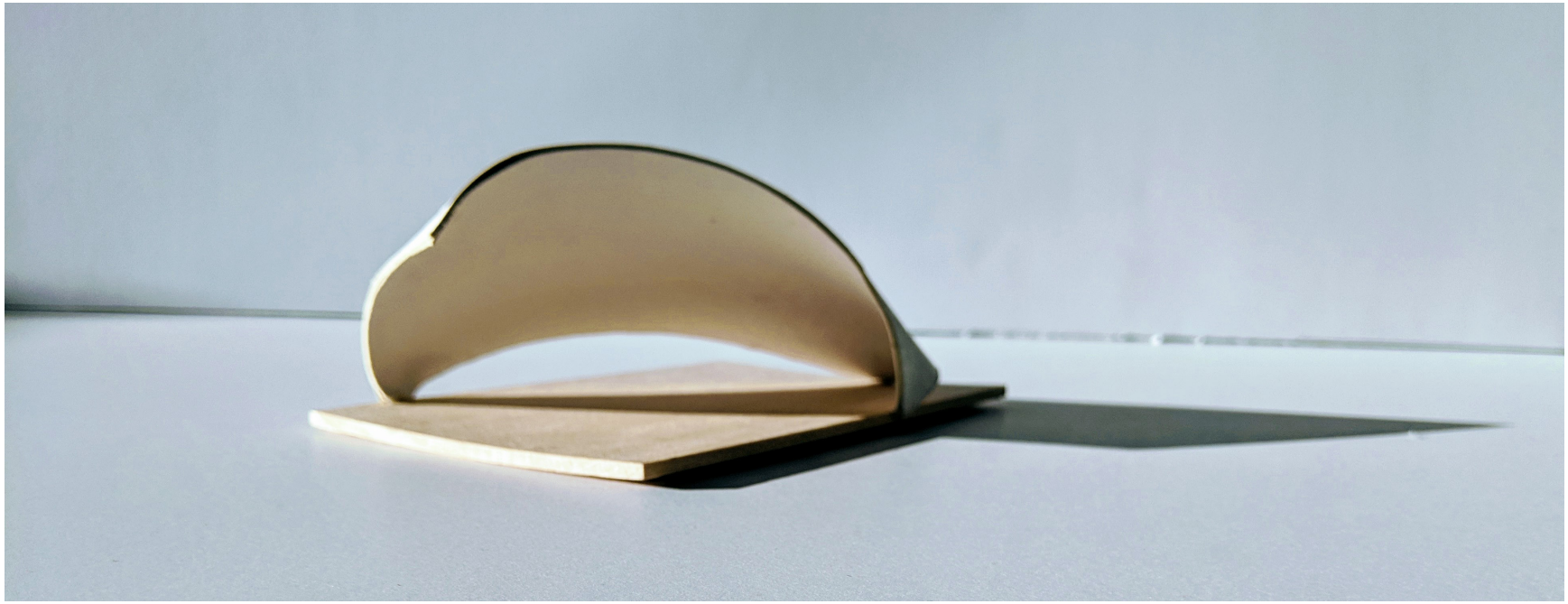


Forming

Shaping

Material: Basswood

Intent: The intent of this model was to create a sense of scooping light.

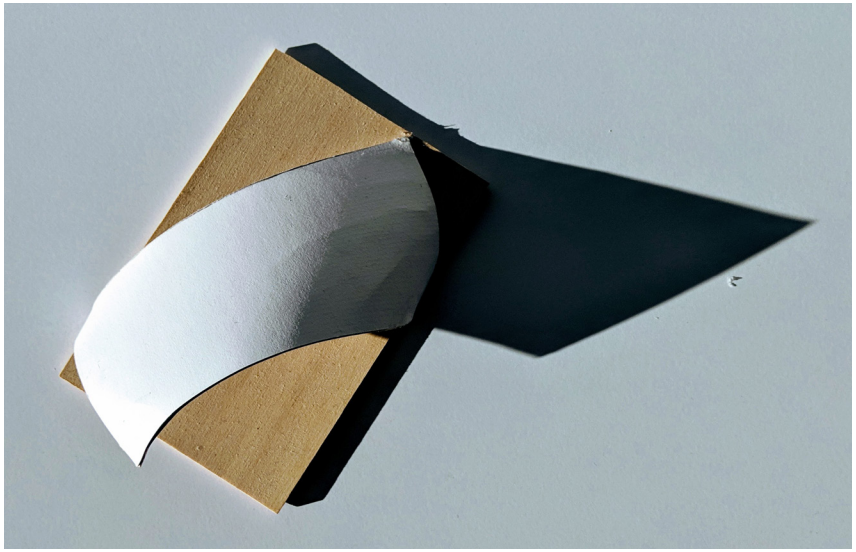


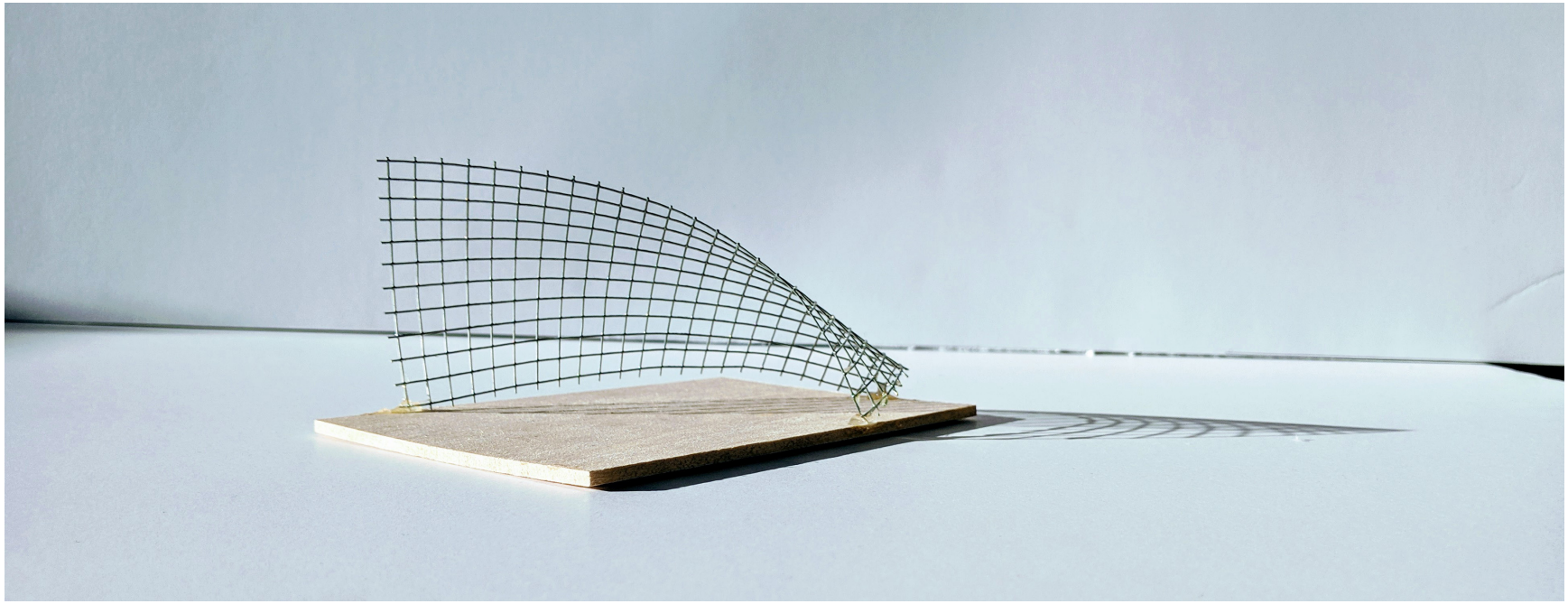
Forming

Shaping

Material: Museum board, basswood

Intent: The intent of this model was to investigate how a sheet could be bent to form a sense of enclosure.



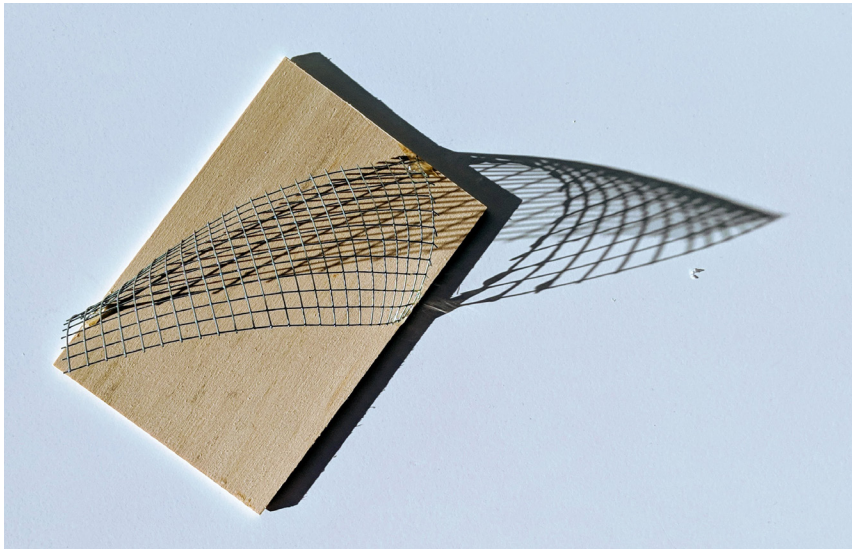


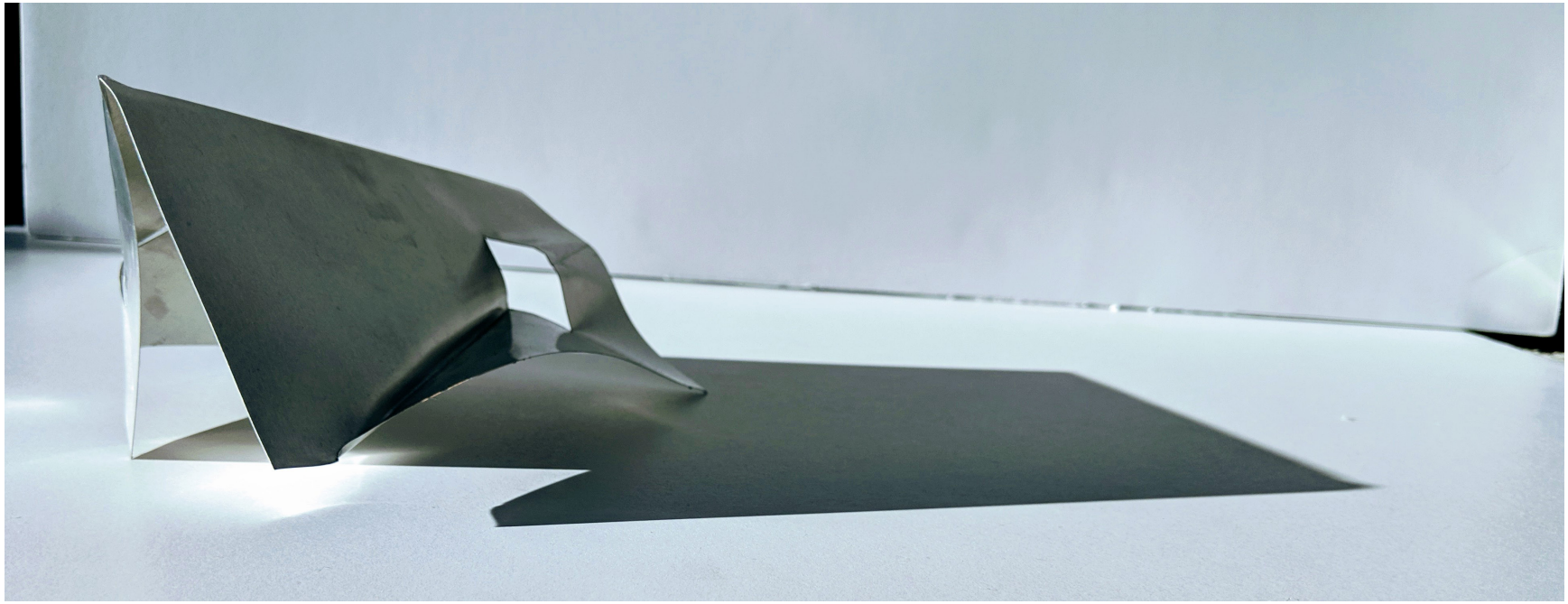
Forming

Shaping

Material: Chicken wire, basswood

Intent: The intent of this model was to investigate how a sheet a porous material could be bent to form a sense of enclosure.



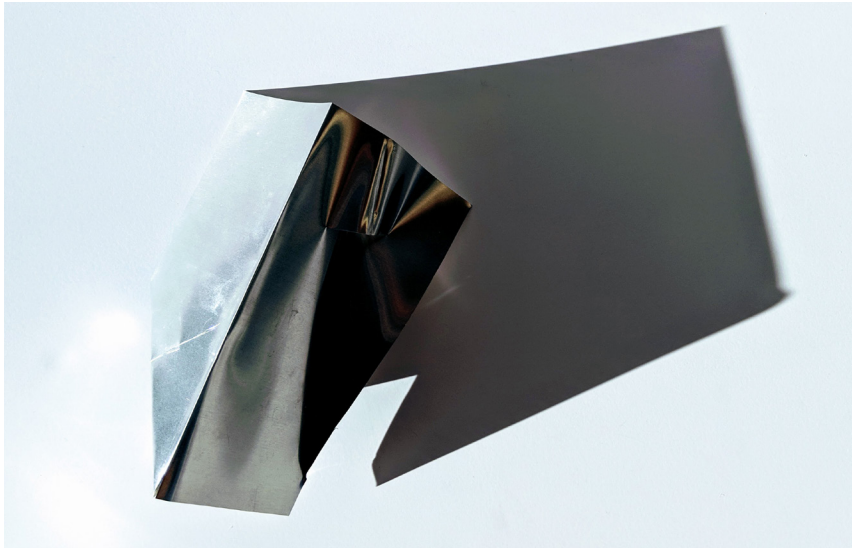


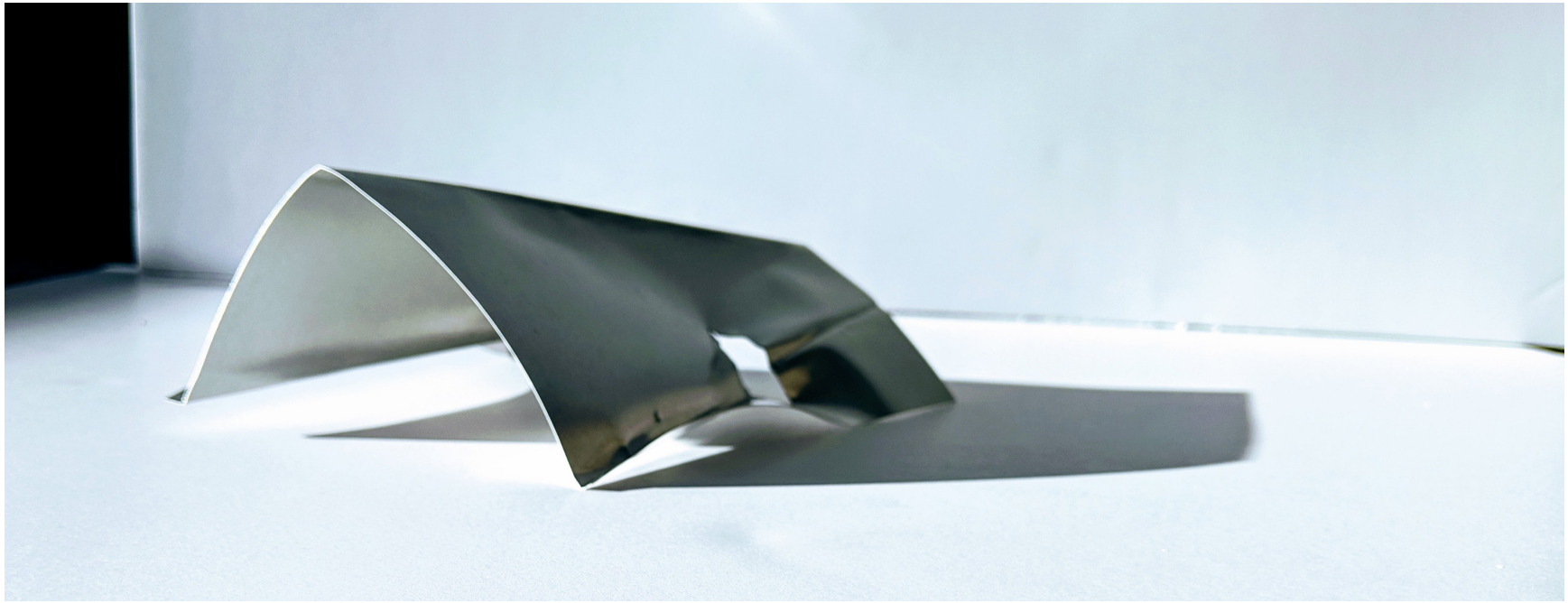
Forming

Shaping

Material: Aluminum flashing

Intent: The intent of this model was to explore the creation of enclosure by folding a flexible material.



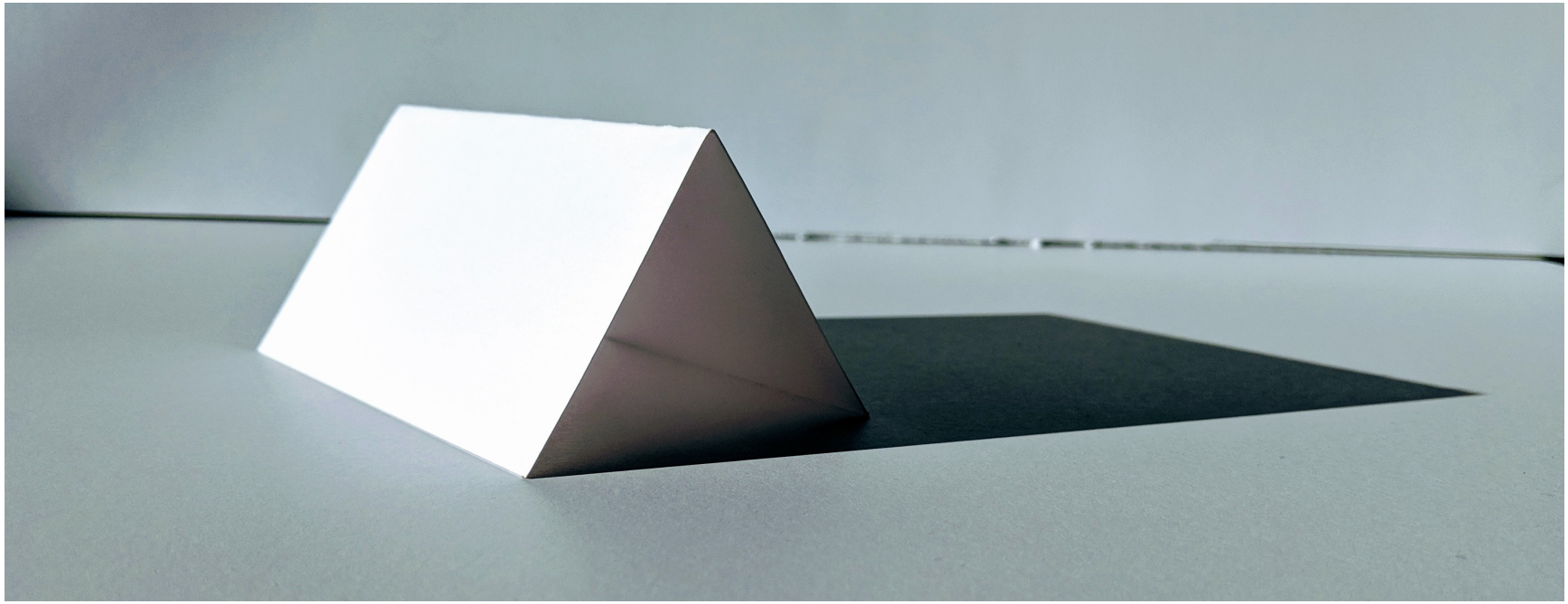


Forming

Shaping

Material: Aluminum flashing

Intent: The intent of this model was to explore the creation of enclosure by folding a flexible material.

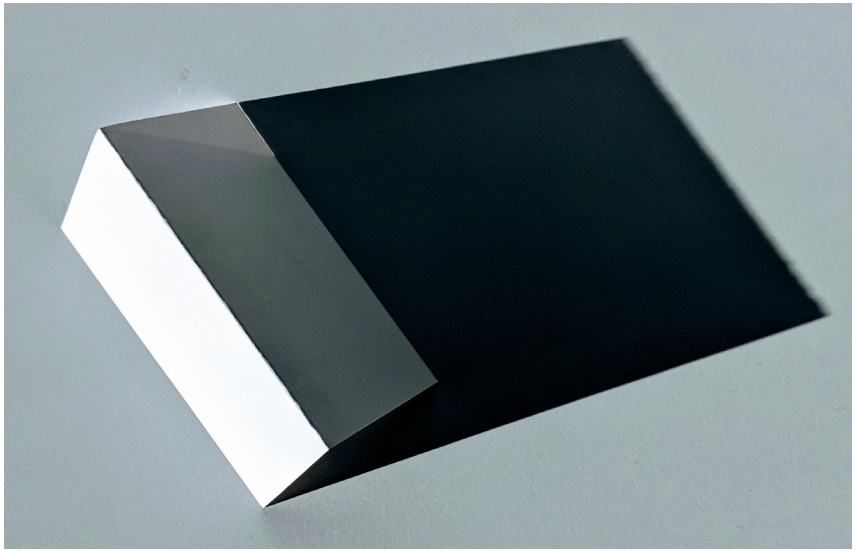


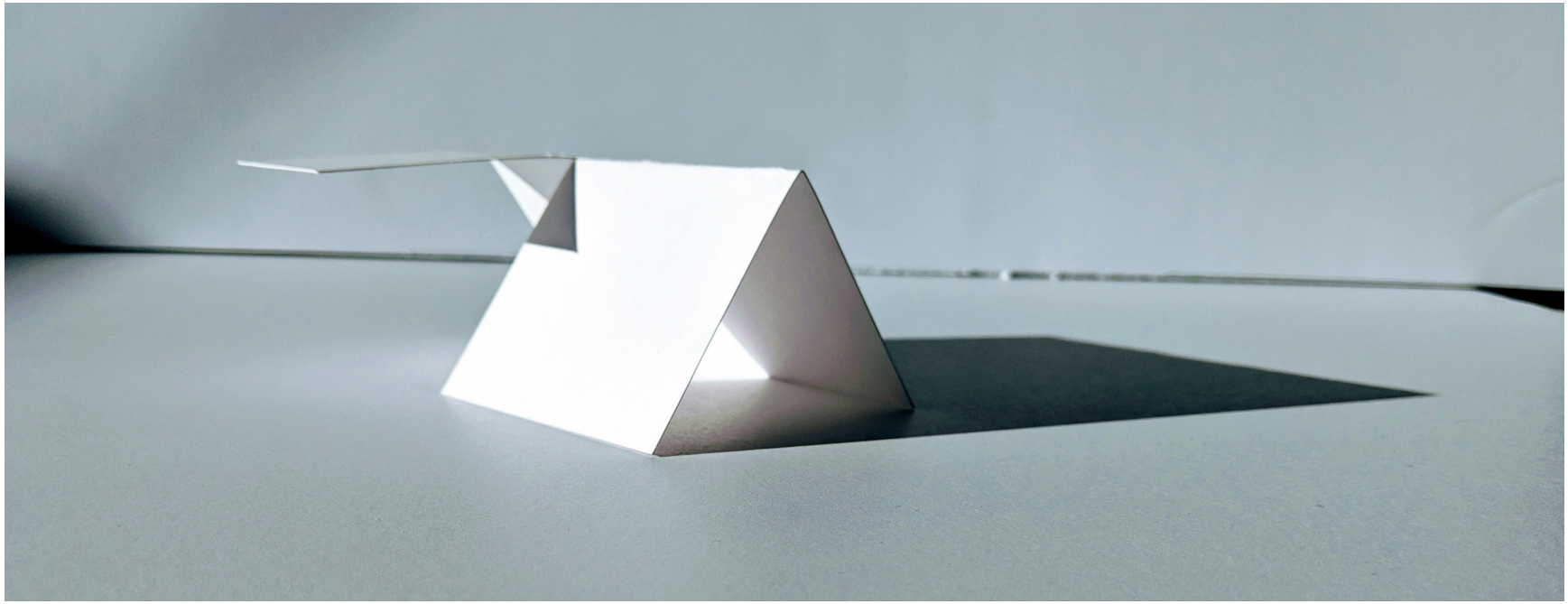
Forming

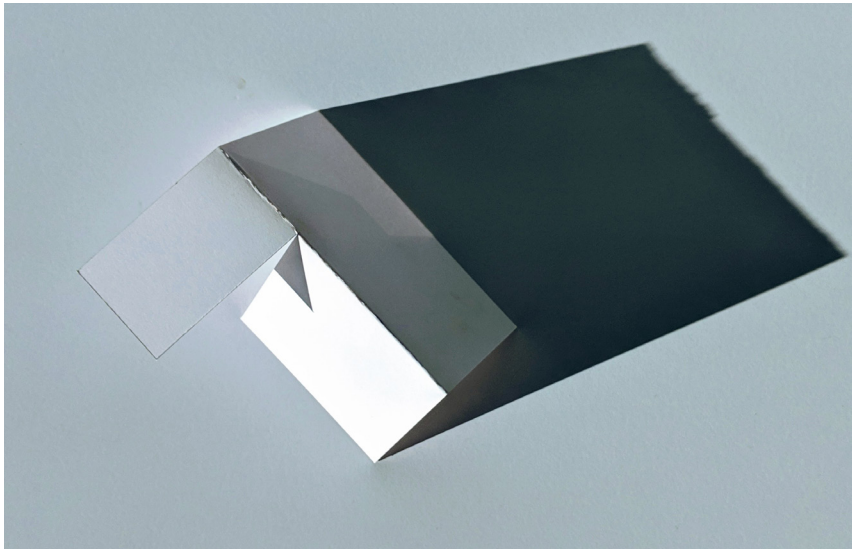
Shaping

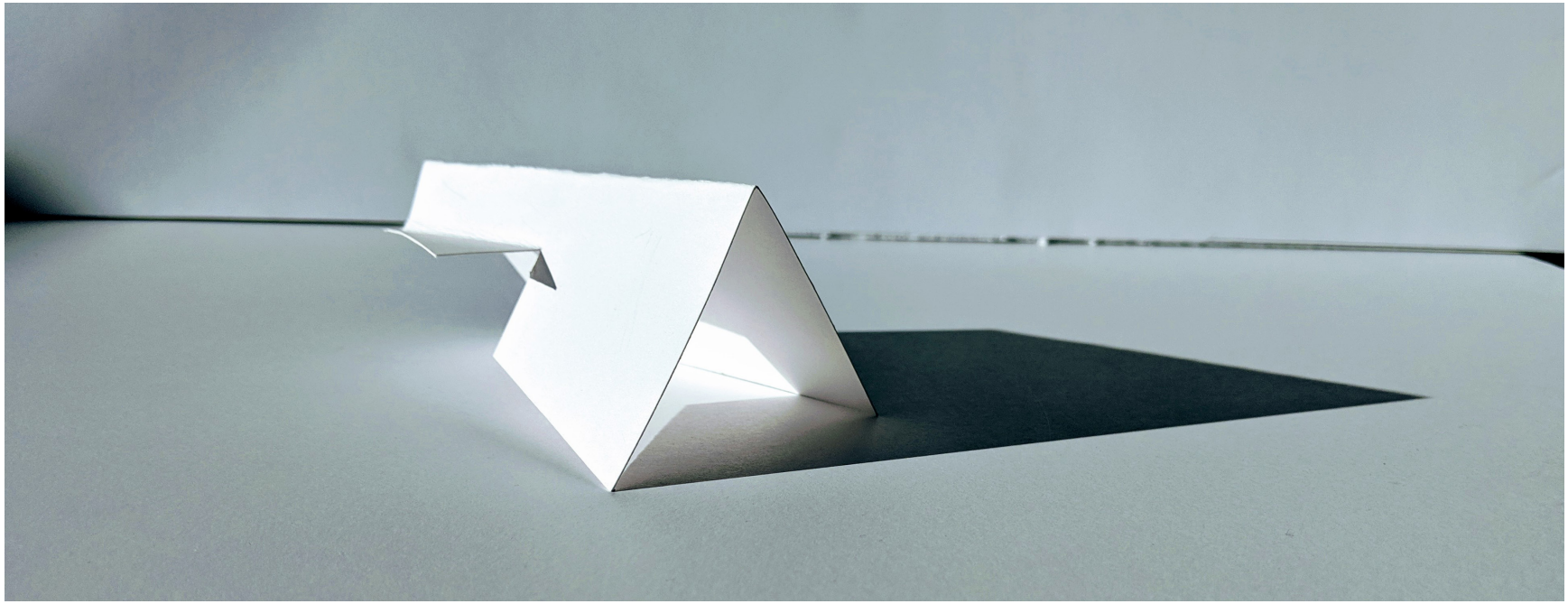
Material: Bristol board

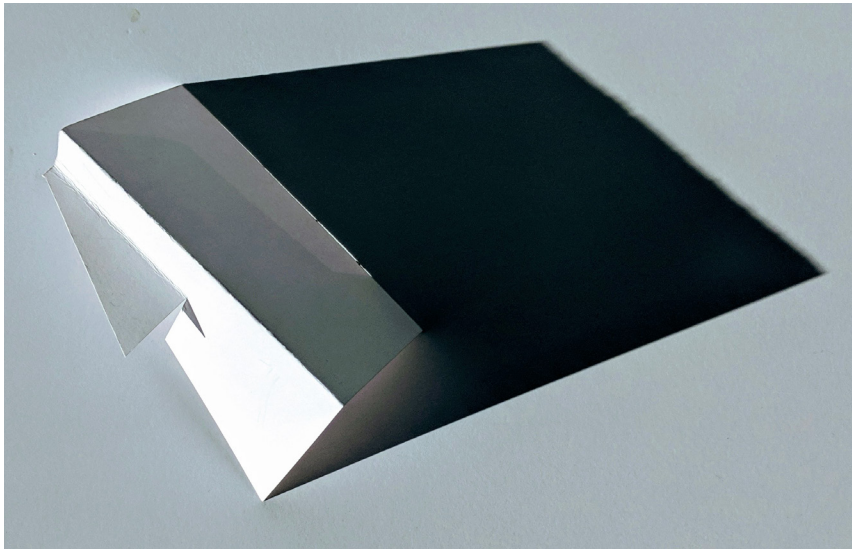
Intent: The intent of these four models was to explore how minor variations in a basic folded shape could create different experiences.

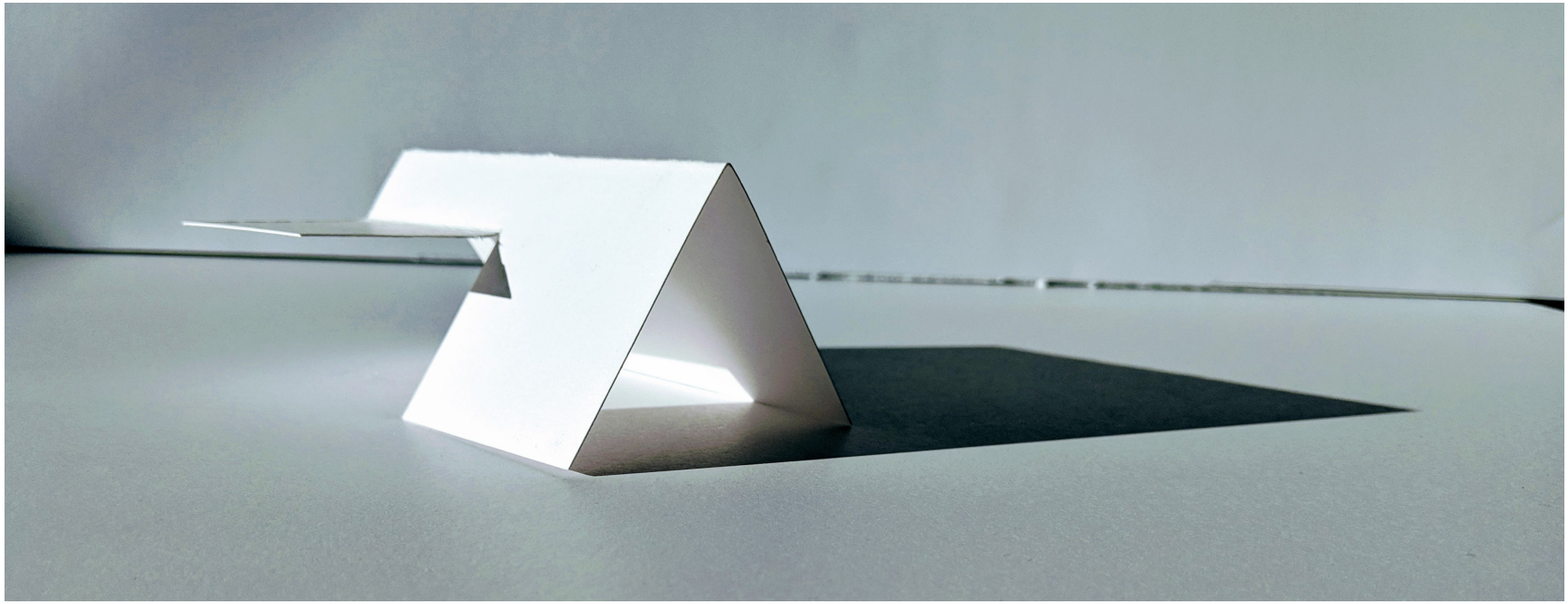


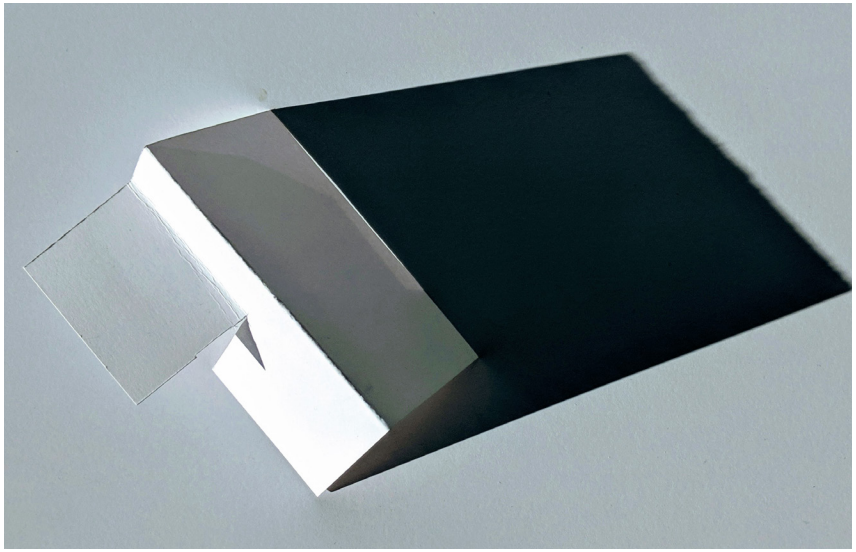


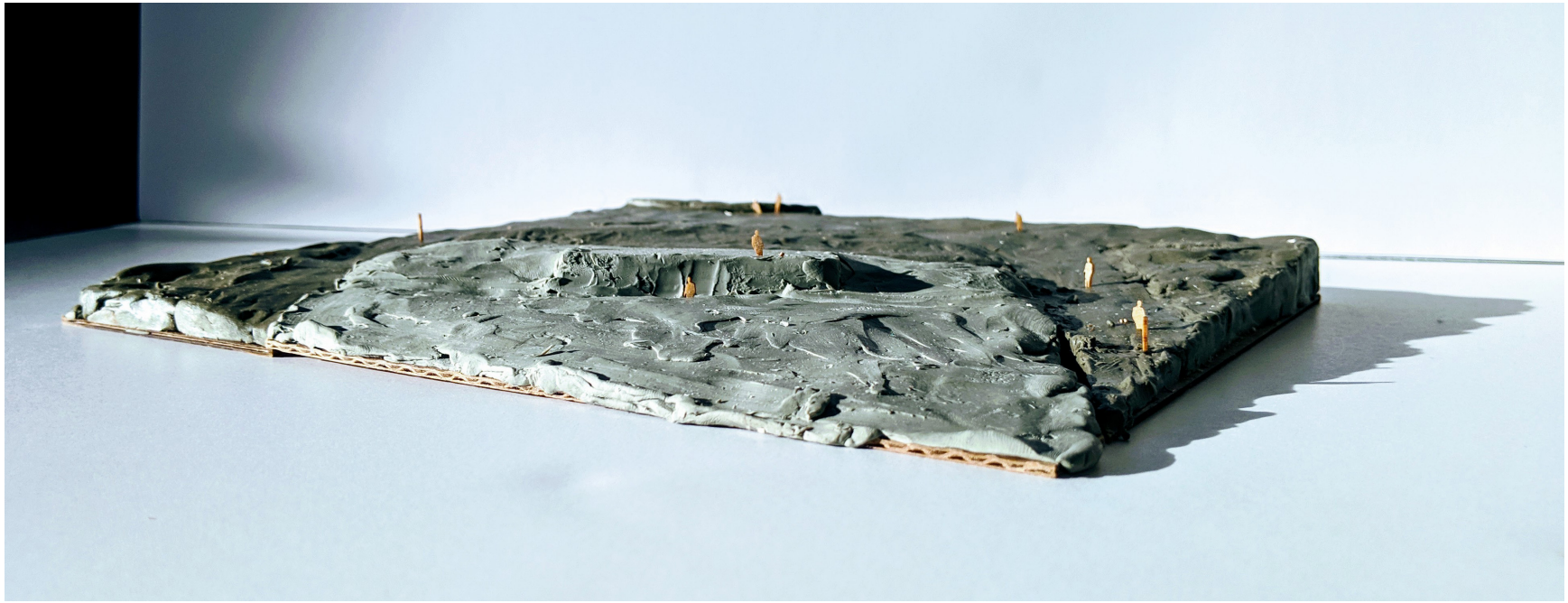










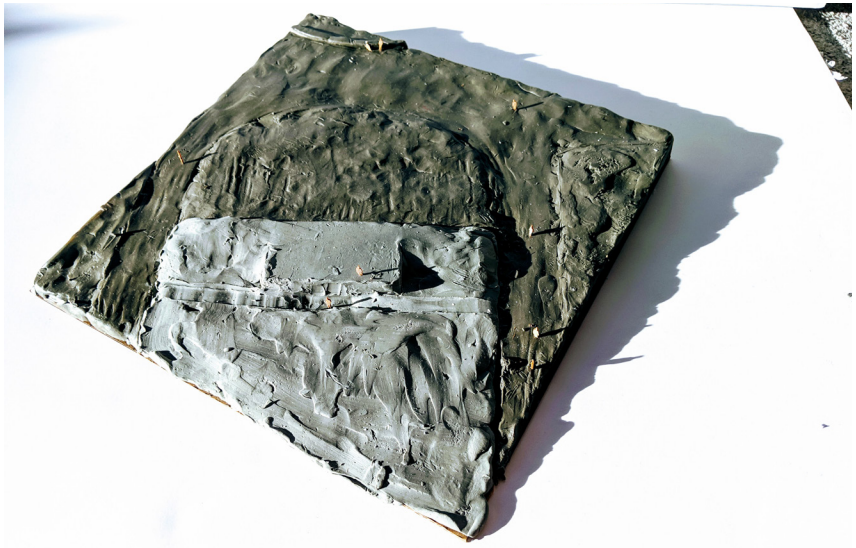


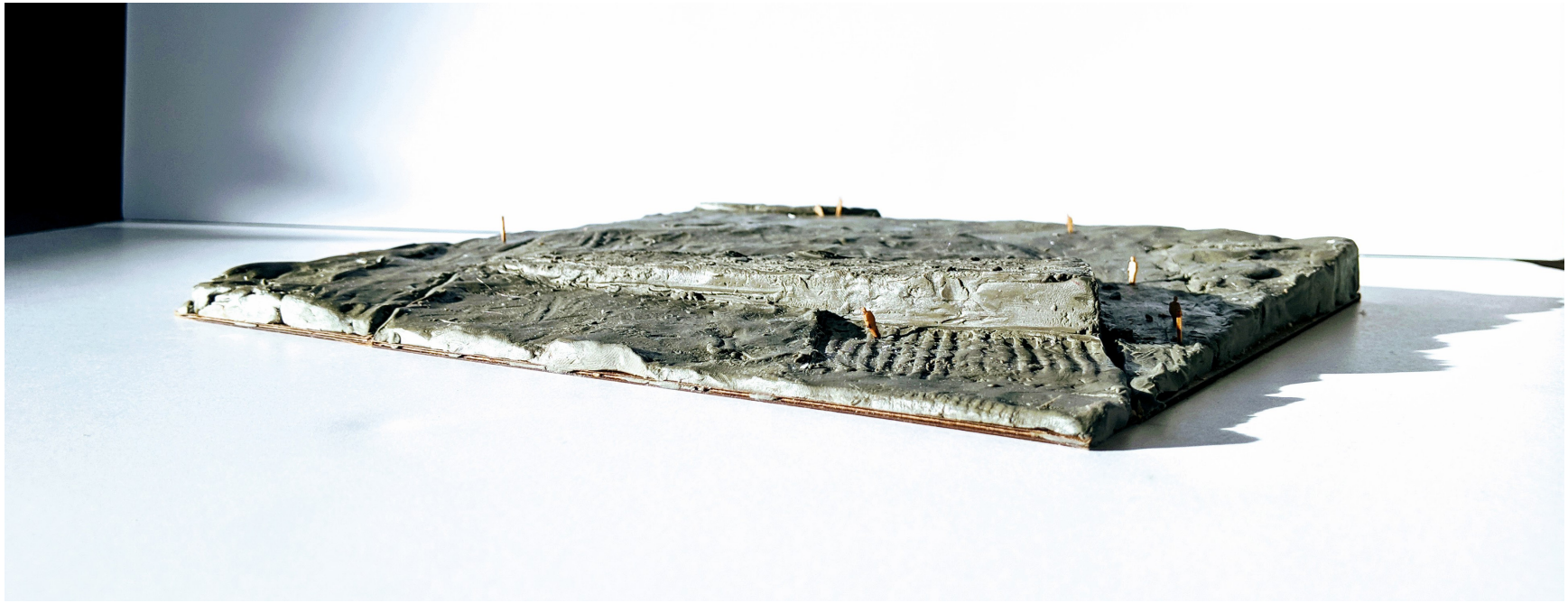
Forming

Shaping

Material: Plasticine clay

Intent: The intent of this model was to explore the manipulation of the ground plane within the context of a site.



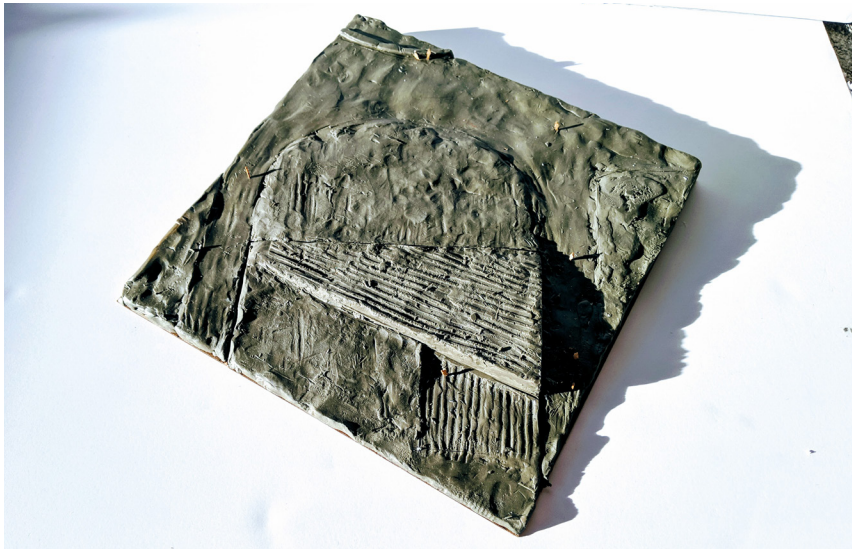


Forming

Shaping

Material: Plasticine clay

Intent: The intent of this model was to explore the manipulation of the ground plane within the context of a site.



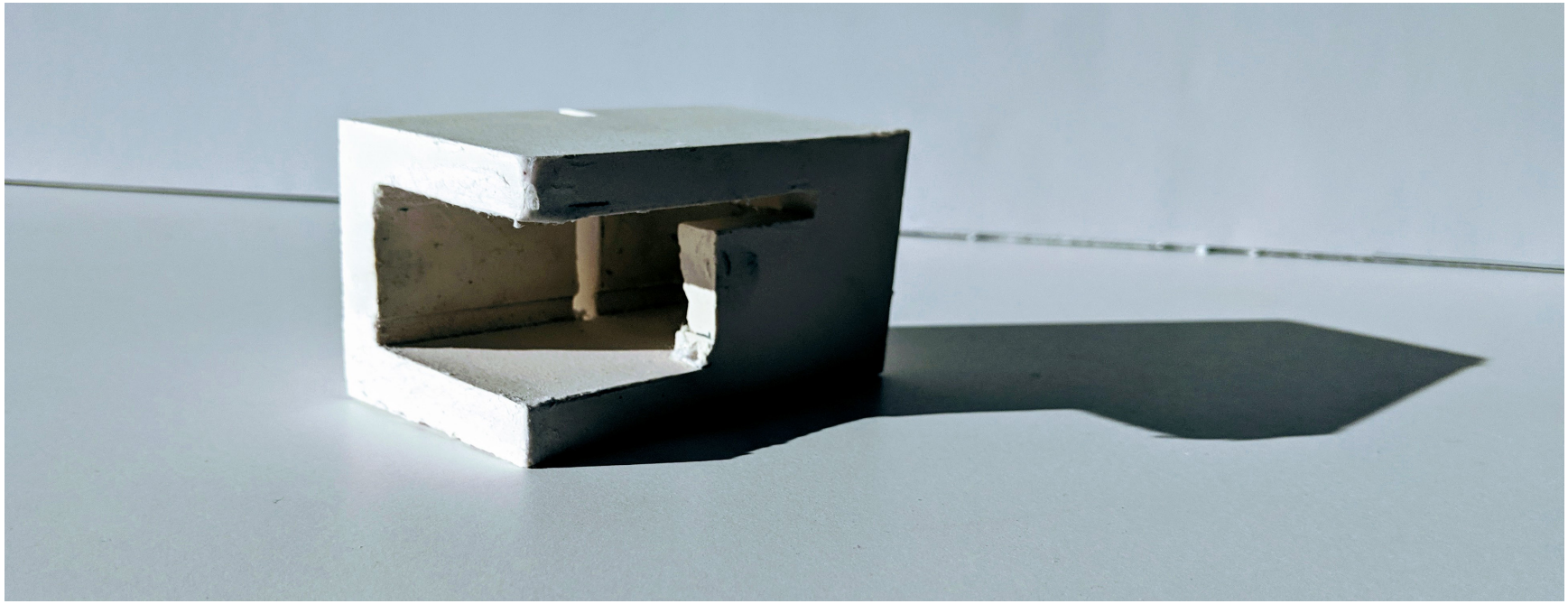
Forming

Shaping

Material: Aluminum wire, plaster

Intent: The intent of this model is to filter light in a uniform way while creating a sense of compression.

Verbs: to sculpt, to shape, to wrap, to fold, to bend, to coil

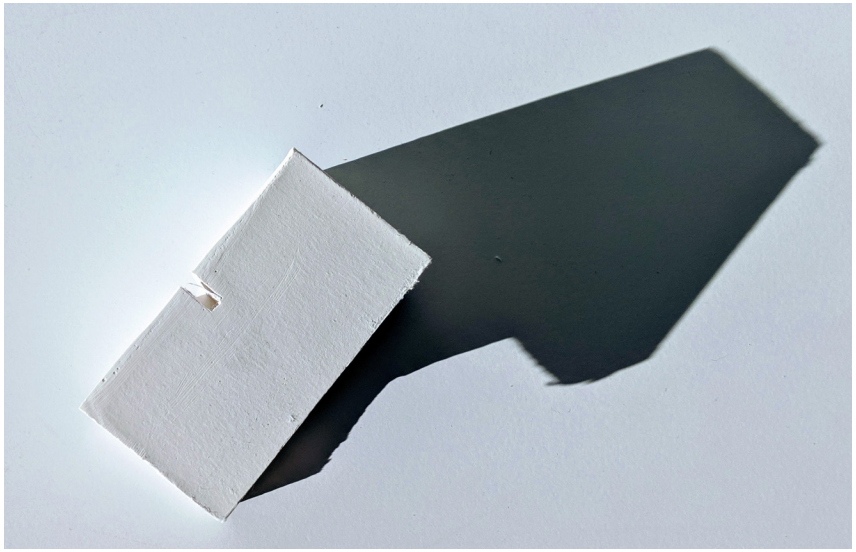


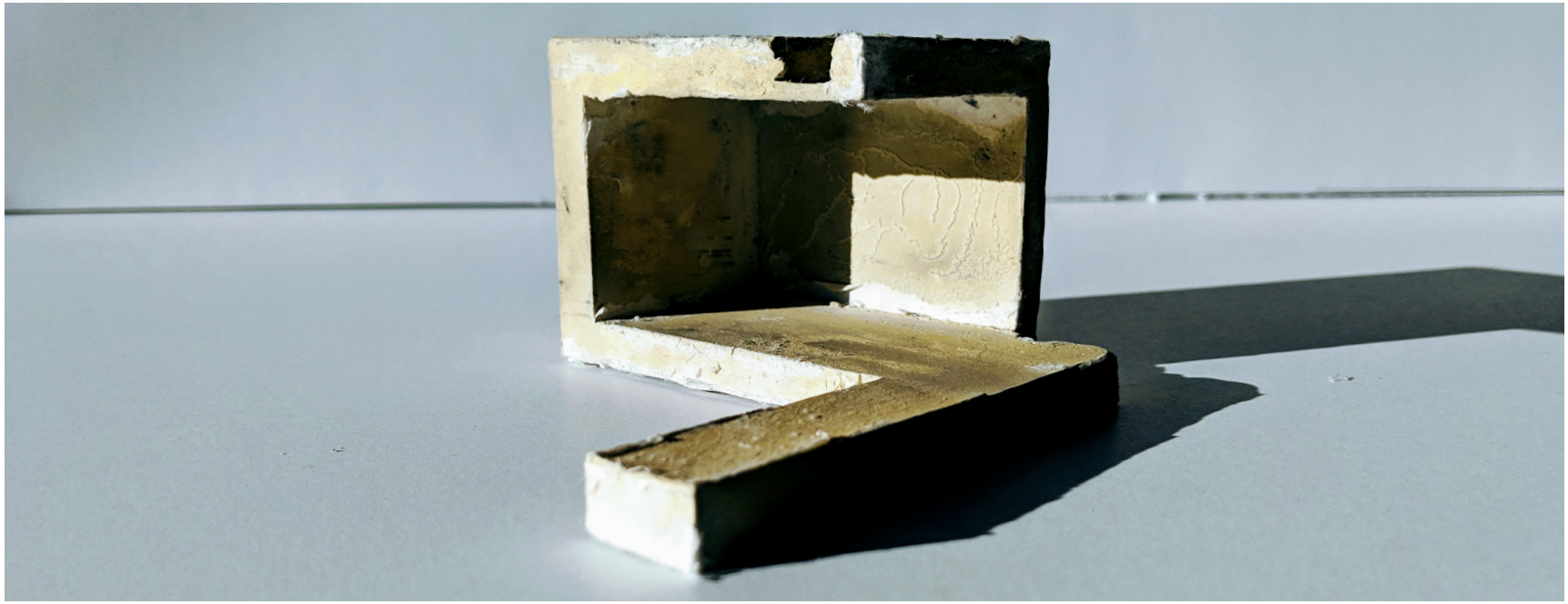
Forming

Casting

Material: Plaster

Intent: The intent of this model was to demonstrate the operation of casting.



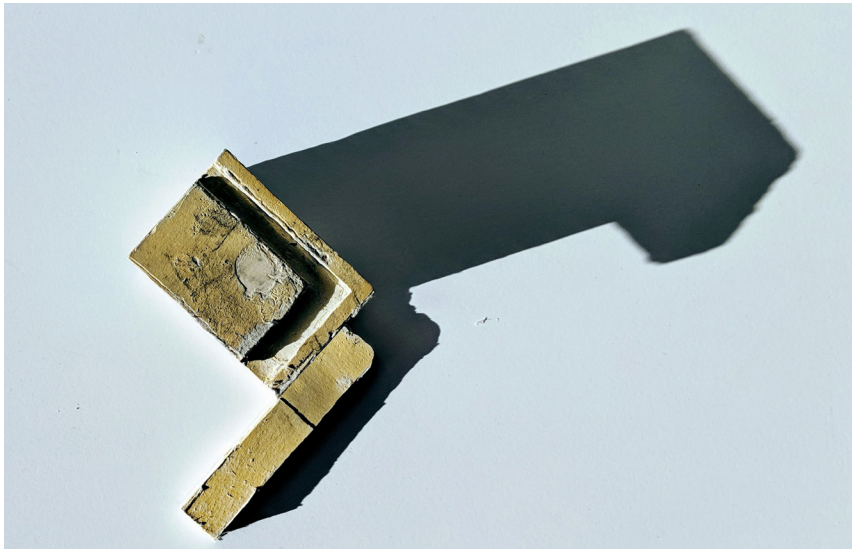


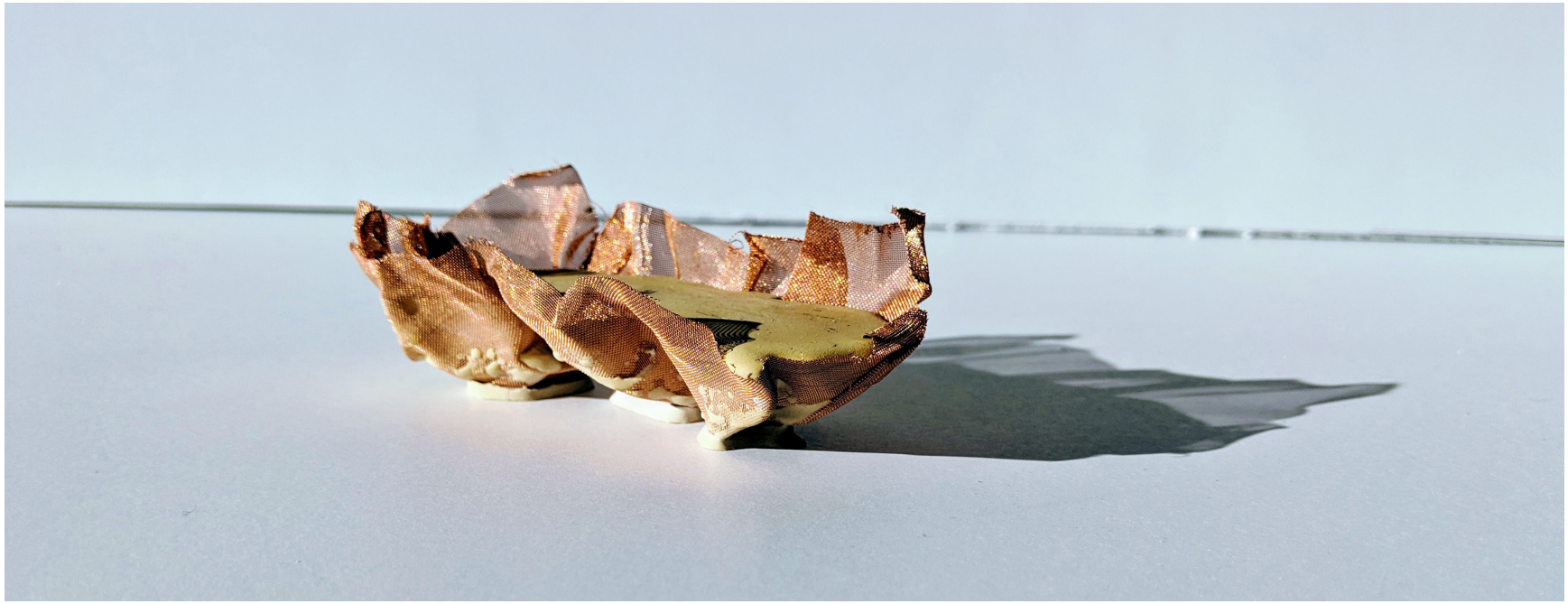
Forming

Casting

Material: Rockite

Intent: The intent of this model was creating a space for contemplating water.





Forming

Casting

Material: Rockite, copper mesh

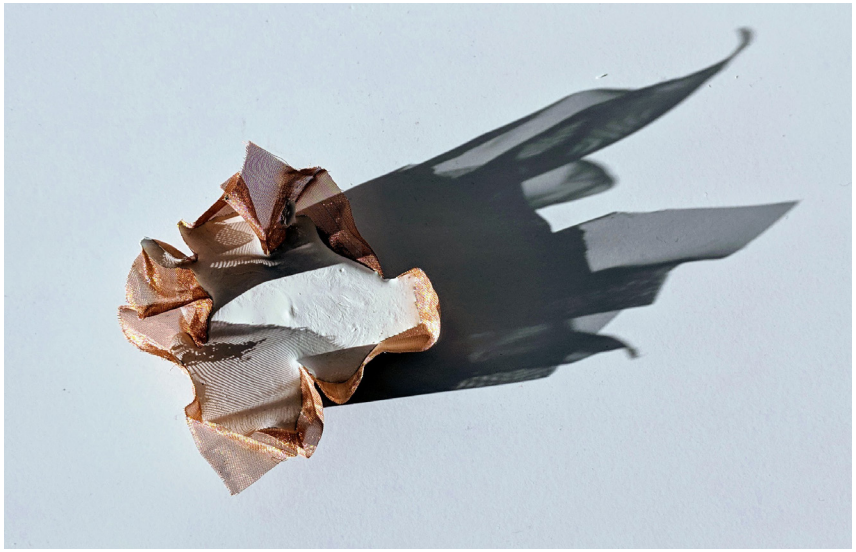
Intent: The intent of this model was to explore something that felt both fluid and solid simultaneously.

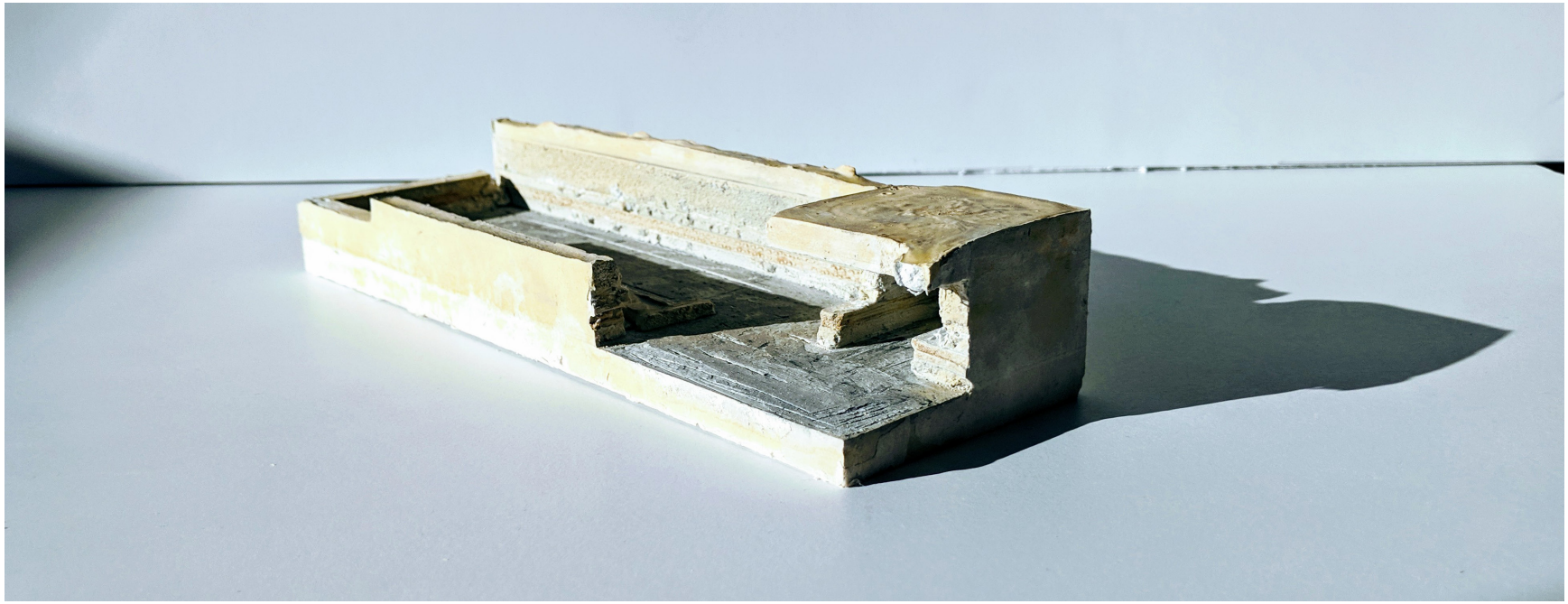
Forming

Casting

Material: Plaster, copper mesh

Intent: The intent of this model was to explore something that felt both fluid and solid simultaneously.





Forming

Casting

Material: Rockite, formwork (would, e-flute, c-flute and foam core.

Intent: The intent of this model was to create a space that expresses the passage of time. To achieve this each layer of the form work used a different material and every shift in the model came from a change in texture.

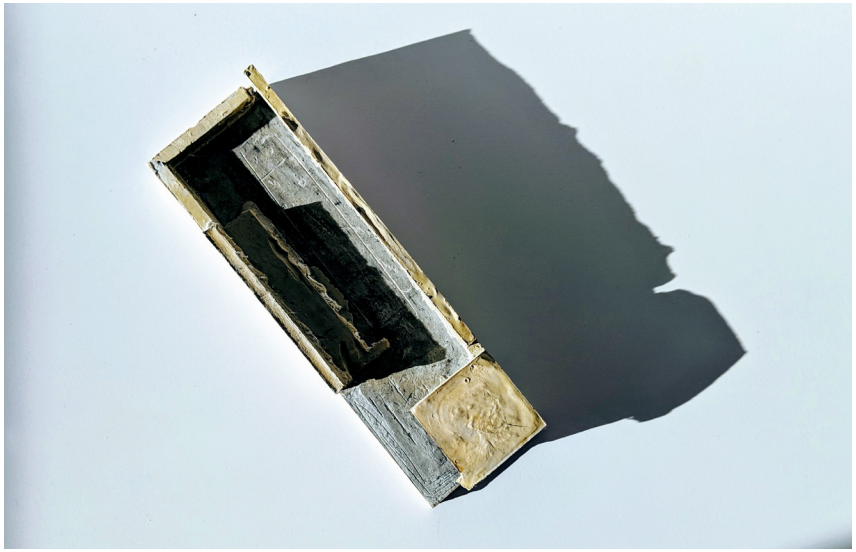


figure 4.94

The categories of operations work well when applied to making models. All the models clearly fit within at least one operation. In many cases a second operation took a secondary role in the making of the object. I found many of the operations played off one another and worked well together.

When multiple materials were used in the same model it created a strong contrast between the character of the materials. That contrast became part of the idea inherent in the model.

This investigation is only the beginning of exploring the possibilities of different operations in the fabrication of models. This is still a small sample of test cases. This is enough to begin to talk about what can be done with the various operations, but it is insufficient to make any claims about their limitations. Further exploration will be required.

This exploration makes it clear that the operations that we choose to employ in making

architectural models have a profound impact on the way that we think about the space and form that we are designing. Our architectural thinking can be embodied in in the way that we create models, the metaphor is in the making.

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Column1	Column2
figure 1.1	Models explored in this project
	Image by author
figure 1.2	Model of Alvar Aalto's Church of the Three Crosses
	"MoMA" Museum of Modern Art, moma.org
figure 1.3	Model of Alvar Aalto's Church of the Three Crosses
	"MoMA" Museum of Modern Art, moma.org
figure 1.4	Photo inside Alvar Aalto. Church of the Three Crosses, Vuoksenniska, Imatra, Finland.
	"MoMA" Museum of Modern Art, moma.org
figure 2.1	Model of Alvar Aalto's Church of the Three Crosses,
	"MoMA" Museum of Modern Art, moma.org
figure 2.2	Material study by Alvar Aalto
	"MoMA" Museum of Modern Art, moma.org
figure 2.3	model by allied works
	“Allied Works.” Allied Works, alliedworks.com/.
	concept model by Allied Works
	“Allied Works.” Allied Works, alliedworks.com/.
figure 2.5	model by Kango Kuma
	Mihoyofuji@comcast.net. “Kengo Kuma Exhibition: a LAB for Materials -.” Zero = Abundance, 6 May 2018, www.interactiongreen.com/kengo-kuma-exhibition-lab-materials/.
figure 2.6	concept model by Kango Kuma
	Mihoyofuji@comcast.net. “Kengo Kuma Exhibition: a LAB for Materials -.” Zero = Abundance, 6 May 2018, www.interactiongreen.com/kengo-kuma-exhibition-lab-materials/.
figure 2.7	material operation diagram from kango Kuma lab for materials.
	Mihoyofuji@comcast.net. “Kengo Kuma Exhibition: a LAB for Materials -.” Zero = Abundance, 6 May 2018, www.interactiongreen.com/kengo-kuma-exhibition-lab-materials/.
figure 2.8	
	“Home.” Patkau Architects, patkau.ca/.

figure 2.9 Model by Patkau Architects

“Home.” Patkau Architects, patkau.ca/.

figure 2.10 diagram showing the six operations of physical modeling

Image by author

figure 2.11 Model by Allied Works

“Allied Works.” Allied Works, alliedworks.com/.

figure 2.12 Model by Kango Kuma

“Designboom Visits Kengo Kuma's Studio in Paris.” Designboom, 16 Jan. 2017, www.designboom.com/architecture/kengo-kuma-studio-visit-paris-designboom-09-21-2015/.

figure 2.13 Model by Kango Kuma

“Designboom Visits Kengo Kuma's Studio in Paris.” Designboom, 16 Jan. 2017, www.designboom.com/architecture/kengo-kuma-studio-visit-paris-designboom-09-21-2015/.

figure 2.14 Model by Allied Works

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figure 2.15 Model by Allied Works

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figure 2.16 Model by Kango Kuma

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figure 2.17 Model by Allied Works

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figure 2.18 Model by Allied Works

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figure 2.19 Model by Patkau Architects

“Home.” Patkau Architects, patkau.ca/.

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figure 2.26 Model by Allied Works
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figure 2.27 Model by Patkau Architects
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figure 2.28 Model by Allied Works
“Allied Works.” Allied Works, alliedworks.com/.

figure 3.1 diagram showing the range of models from conceptual to real.
Image by author

figure 3.2 Model by Allied Works

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figure 3.3	Model by Patkau Architects
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figure 3.4	Model by Patkau Architects
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figure 3.8	concept model by Kango Kuma
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figure 3.18	Model by Patkau Architects
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figure 4.1	a diagram showing how the operations work on models in the project.
	Image by author
figure 4.2	a diagram showing that the project is focused on the conceptual side of model making.
	Image by author
figure 4.3 - 4.93	show images of models built for the project. each model is explained within the text.
	Image by author
	Models explored in this project
	Image by author