Open Thermodynamic Design: Exploring Dialectic Design Processes Through Mass Timber

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This paper examines a pedagogy that seeks to resist conventional approaches to the relationship between design and energy in architecture and instead advance our ability to address environmental concerns as designers through a dialogue with material utilizing criteria such as its material sourcing, carbon footprint, and microclimate as drivers of design. This dialogue welcomes material agency as an active and critical participant in establishing the form and performance relationship. This paper articulates the process utilized in a three-credit seminar that asked students to design a mass timber cabin sited on a tree farm. The material for that cabin must be harvested from the site. This process asks the students to consider a series of dialectic relationships between the material, the site, the form, and the microclimate of their cabin. This reciprocal design process that repeatedly changes scales allows the students to engage environmental design as a systematic dialogue at multiple scales of time, space, and energy establishing an interconnected relationship between form and performance.

This paper articulates the process by which students were given a site in which they harvest a set amount of timber and then use that material for the construction of a small mass timber cabin located on the very same site. Each iteration involved tumbling the cabin into different positions and asking the students to account for a new seasonal criterion. Each tumble reterritorializes earlier design decisions and requires the students to reevaluate those decisions under new material and climatological conditions. The cabin has three positions, summer, fall, and winter. Each position requires the students to address climate issues such as buoyancy ventilation, cross-ventilation, and the stratification of air. As the students make design changes, they harvest more lumber from the site. This creates a series of dialectic relationships at multiple temporal and spatial scales. Key issues, such as the number of trees cut down and the scale of their cabins, are tempered by discussions around embodied and sequestered carbon. This paper examines how these speculative projects ask students to consider design as part of an open thermodynamic system in which the building is a momentary physical manifestation of larger energy and material flows by speeding up certain.

INTRODUCTION

Increasingly architects are asked to design buildings that address the environmental concerns of our contemporary and future conditions. This is typically achieved through adherence to well-established standards and guidelines. While programs like LEED have provided much-needed clarity, that clarity has come at the expense of a more comprehensive assessment and radical innovation. As William W. Braham notes, LEED has increased the market penetration of environmentally focused practices, but it has done little to promote the necessary fundamental change.[1] Design education has traditionally seen environmental issues as part of the building technology pedagogy and not the studio pedagogy. While this trend is changing, with the revisiting of formal agendas related to hieliomorphism, for example, this approach to integrated building science into the design studio only tackles environmental forces that have an explicitly geometric relationship to the form of the building. Issues related to building energy performance or the holistic impact of the building on the environment are left to the technical courses to teach and reflect the regimes that developed them. A new pedagogy is needed to give students the core design skills that will allow them to meaningfully engage nonformal influences on a building through the formal mechanism of the architectural profession. A pedagogy that seeks to resist these established approaches to the relationship between design and energy in architecture and instead advance our ability to address environmental concerns as designers through a dialogue with material utilizing criteria such as its material sourcing, carbon footprint, and microclimate as drivers of design will push the profession forward. This dialogue welcomes material agency as an active and critical participant in establishing the form and performance relationship. This process asks the students to consider a series of dialectic relationships between the material, the site, the form, and their cabin's microclimate. This reciprocal design process that repeatedly changes scales allows the students to engage environmental design as a systematic dialogue at multiple scales of time, space, and energy establishing an interconnected relationship between form and performance.

This paper articulates the process utilized in a three-credit seminar that asked students to design a mass timber cabin sited on a tree farm in which the material for that cabin is harvested from the site. This process asks the students to consider

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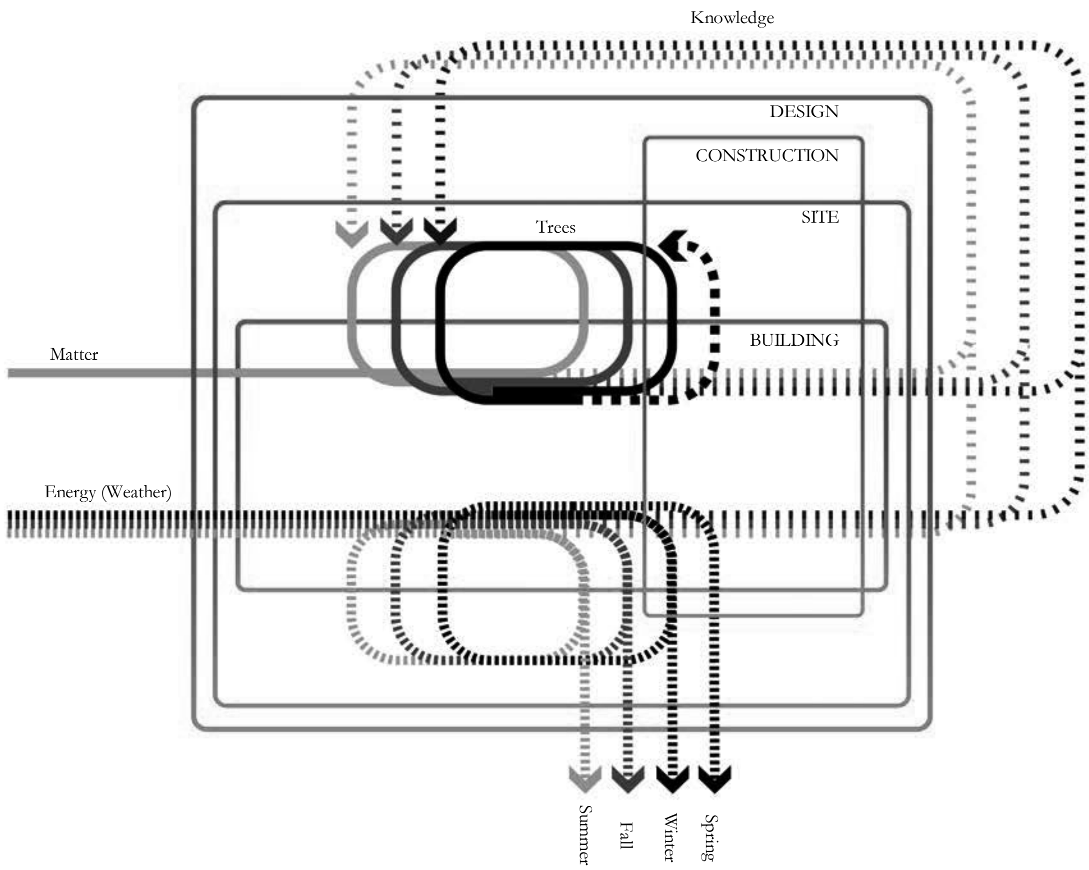

Figure 1. Course Design Process System Diagram

a series of dialectic relationships between the material, the site, the form, and the microclimate of their cabin.

PEDAGOGICAL CONTEXT

Architectures' relationship to energy and design prioritizes efficiency and management of energetic systems. HVAC components are designed to work more and more efficiently while building envelopes become more insulative. While many modern energy and ecologically sound systems around buildings such as LEED or Living Building Challenge address the building as a system, the methodologies we use to teach these issues continue to languish in the technology courses of the academy.[2] These courses eschew the studio-based education for the objective outcome found in the sciences. The introduction of issues surrounding carbon has not changed this dynamic. Life Cycle Analysis, an industry tool for evaluating the carbon footprint of a building, views the building as a collection of numbers accounting for every material's impact on the building.[3]

The basis for this exercise comes from Howard Odum's understanding of systems ecology and two particularly important concepts one the system boundary and two the idea of an open system. [4] We know that an open system differentiates itself from a closed system as it is able to exchange energy and matter with its surroundings. We can conceptualize all aspects of architecture in this way: the site, the building, the material that we harvest for that building, and potentially even the design process itself for this exercise by reconceptualizing the design process as an open system one in which matters and energy enter the system and leave the system through the design process all we need to add is the byproduct of the iterative design process of knowledge.

In this case, the exercise is reconceptualized as an open system in which design is a system boundary, meaning that the process that the students are going through is part of the overall system, and while energy and matter may not be directly be coming from the design process, conceptually they key. Rather than a series of isolated iterations, this process has the students dialectically and cyclically working on a single cabin. We reconceptualize the design process or even the iterative process as one in which the matter and energy in which we apply to our artifact, in this case, a one-room cabin, is constantly changing. That constant change decontextualizes and recontextualizes the design work of the previous iteration. Design decisions made in the previous loop have to be contended with in the 2nd loop. Environmental criteria in which you need to design for in the 1st loop has to be can contend with or addressed in the 2nd loop, meaning that if a cabin is designed to address the summer needs, then it has to continue to address the summer needs even after it's been manipulated to

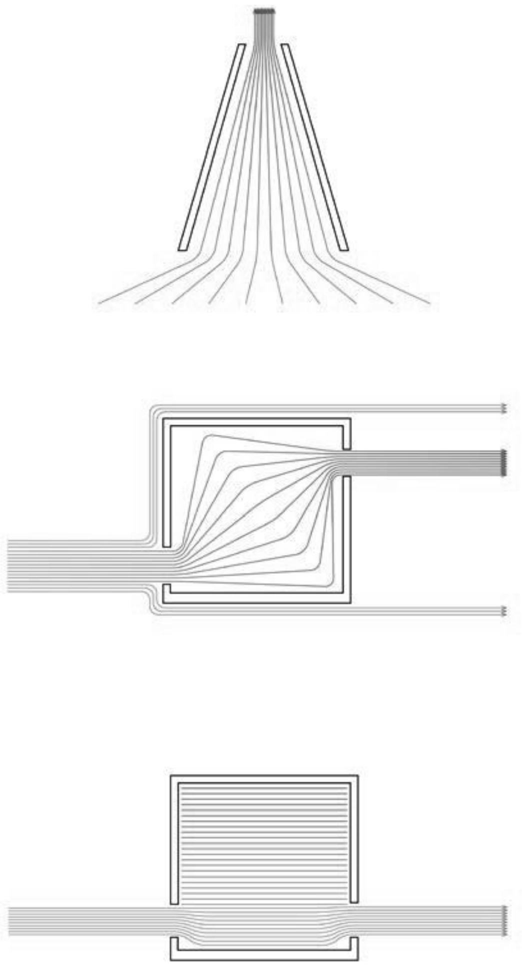

Figure 2. Enviromental design criteria, Summer, Fall, and Winter.

address the fall needs. In addition to this, I add one wrinkle to this that helps to decontextualize the design process between each iteration. (Figure 1)

To support these endeavors, the students are taught industry-standard clt and glue-laminated timber details, which allow the students to gain a mastery of the basic construction. These details are then used throughout the semester. They are also taught the basics of wood harvesting and timber production so that they understand where the embodied carbon numbers are coming from. Finally, students are given an overview of timber construction so that they see how engineered mass timber is related to an evolution of timber construction historically.

SITE AND RECIPROCITY

The exercise starts with giving the students a plot of a tree farm. The tree farm has a series of paths that run through it that connect each of the sectors of the tree farm. Students are given specific information about the number of trees, their age, and relative size. This information facilitates the accurate calculation of the total mass included in the cabin and thus the total number of trees that need to be cut down to supply the cabin with timber. This introduces the first important feedback loop of the project: Lumber used to create the cabin is extracted from the site of the cabin itself.

This extraction requires suspension of disbelief as it relates to the time it takes to produce CLT or Glue laminated lumber from fresh-cut trees. The entirety of this process is covered in the class through lectures. The site then becomes a patchwork of carvings into if the field condition that is the forest. These new carvings become pathways and clearings that facilitate the student's design ideas and become a spatial representation of the material that goes into each cabin. This is complicated by the next step of the project, which we will cover in the next section.

PART 1_SUMMER CABIN

The first iteration of the first cycle for the cabin is what's called the summer cabin. This iteration establishes the basic criteria of the cabin. For example, the project is a 200 square foot single-room cabin, and the students must provide a way to view out of the cabin, lay down and sit within it. Additionally, seasonally specific criteria are given. This specific criterion is the primary environmental driver of design. In this iteration, the cabin needs to deal directly with buoyancy ventilation. The cabin needs to be shaped to support the flow of air. The students have given lectures that lay out the specific ways in which buoyancy ventilation can be achieved. Sections from Design with Climate are leveraged throughout the semester.[4]

The early iterations of the summer cabin were incredibly reductive. Students defaulted to the basic understanding of a "Cabin." A number of the students produced a pitched roof profile with no formal inflection of the buoyancy ventilation. These cabins were able to achieve the primary criteria given that that form was able to achieve buoyancy ventilation. The lack of formal exploration was acceptable as long as the students were using the first iteration to explore the basic understanding of typological responses to buoyancy ventilation. This is also the first or one of the first dialectic aspects of this project as students are making design decisions based on environmental factors which require the harvesting of a certain amount of material. That harvesting needs to be designed in order for the site to accommodate the cabin that there also at the same time designing.

PART 2_FALL CABIN

After the summer cabins are presented with the system's boundary of project shifts, I ask them to rotate their cabins 90 degrees. The students tip their cabin onto its side, and in doing so, we decontextualize moves from earlier design briefs. Now a door becomes a skylight, and a window now looks at the ground; things that were used to drive buoyancy ventilation

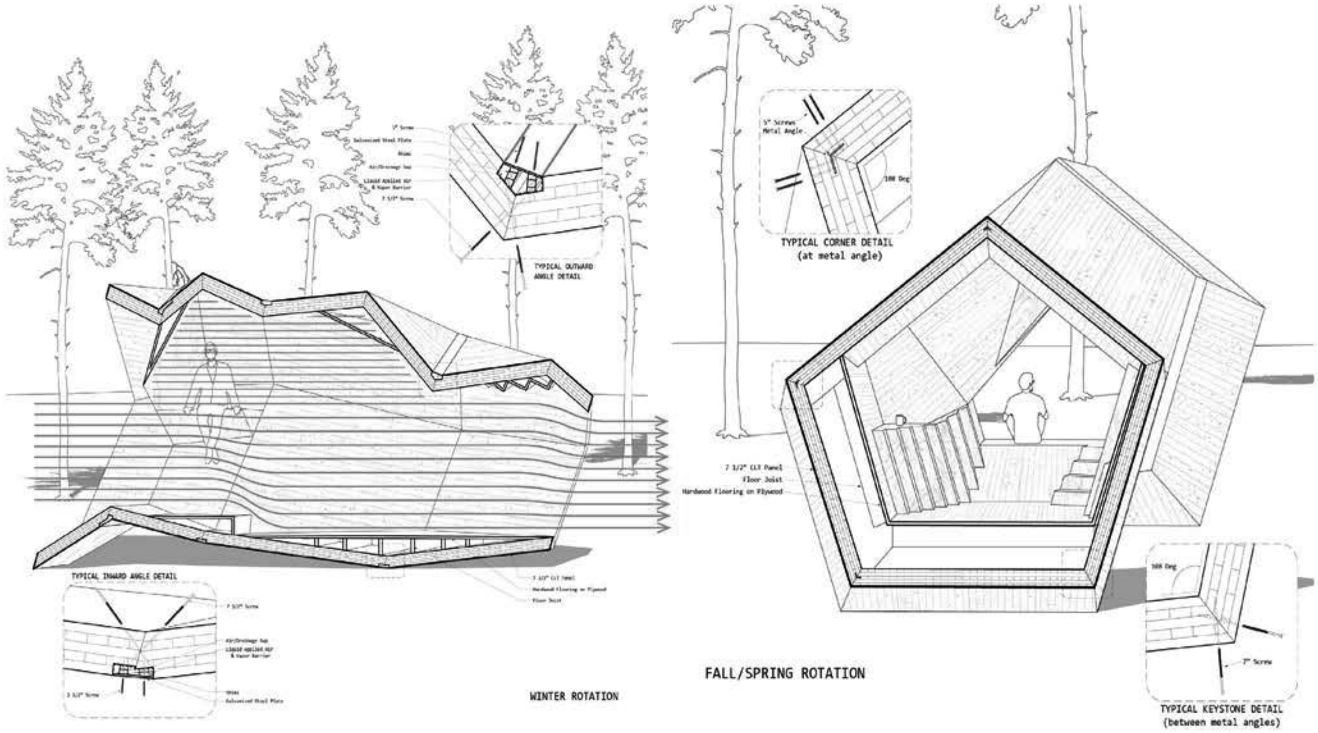

Figure 3. Fina l Drawings by Kalle

are now closed off and maybe not working. Accompanying that rotation, or tumbling, of the cabin, we assign a new environmental criterion. We are no longer worried about the summer condition or mode. Now we're worried about the fall condition or mode. In the fall, cabins must provide cross ventilation. Each student has to decide about how their cabin would tumble and how they might remove trees to facilitate that, which was then governed by the actual mass of their cabin. This is the first time the students have to contend with their own design decisions as well as the environment changing around them. This dialectic process is its self an open system. The caveat being that the addition of material and shifting of system boundaries are given by the faculty and the student's previous decisions.

PART 3_WINTER CABIN

This process happens two more times. Each time the cabin is tumbled, and a new environmental criterion is applied, and the students need to account for their previous design decisions. For the winter cabin, the space must provide a form to capture hot air rising. The projects must now specifically deal with the phenomenon of striated air.

PART 4_SPRING CABIN (REFLECTION + DELIVERABLES)

The final iteration in the cycle is the spring cabin. As with the fall cabin, this iterations criterion is cross ventilation. Some students used this as an opportunity to further develop other aspects of the project, while others simply used this iteration to refine the total design. After this iteration, we work with the students to develop a set of detailed drawings and models which will be presented at the final review. (Figure 3)

EMBODIED CARBON AND DESIGN DECISIONS

Along the way, we used embodied carbon as a touchtone or datum that allowed us to think about the amount of material going into each of these designs and give the students a criterion that we could use to evaluate our projects in a slightly different manner. Each step along the way, we compared a similar project that was similar to the design of the student's project but made out of concrete or steel. This allowed the students to connect design decisions about wall thickness, which might have analogs in the concrete design of their project but, in fact, are much more carbon-intensive. This was an essential analytic tool for the students to understand that formal design decisions have consequences beyond the shape of the building.

FORM AND THE GENERATIVE PROCESS

In the end, we saw a dramatic change from the first iterations to the more emergent final designs. The rudimentary forms of the first iteration are still present in the final designs, but they have been mutated by the cyclical design process. In the process of rotating the cabin and applying new climate or environmental criteria, new forms and types of occupations emerge. They are made possible by the systemic design process, which generates unexpected results. (Figures 4 and 5)

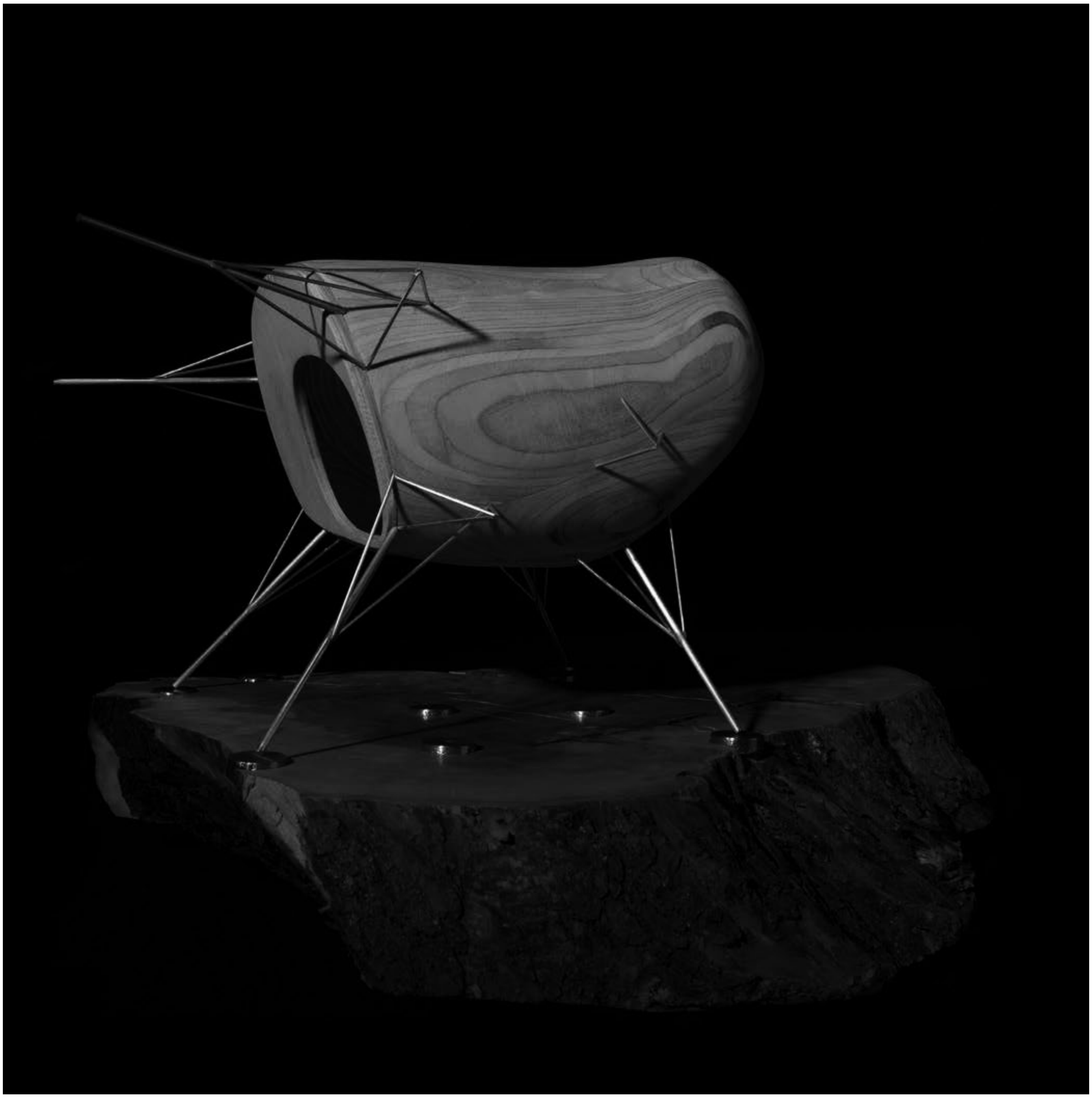

Figure 4. Final Model by Keygan Sinclair

CONCLUSION:

In order for students to tackle design as a system and innovate architecture beyond simply efficiency, they need new design skills. This paper briefly lays out a single project and the process of shifting the system boundary of a project to achieve this goal. This act of changing design criteria while the students work on a single object allows the students to better understand a new way for architecture to address environmental issues. This process seeks to reorient architectural design to systems thinking in which the design process itself is an open system. This system in which energy and matter are added to the project idea or design process reshapes the criteria of design to a compromise between the student's earlier decisions and the new environmental criteria applied from the site. As it relates to carbon, having the design process engage carbon as a datum and as a driver through the use of mass timber gives the students a check outside of the subjective nature of the design. Driven by this series of repetitive or cyclical design

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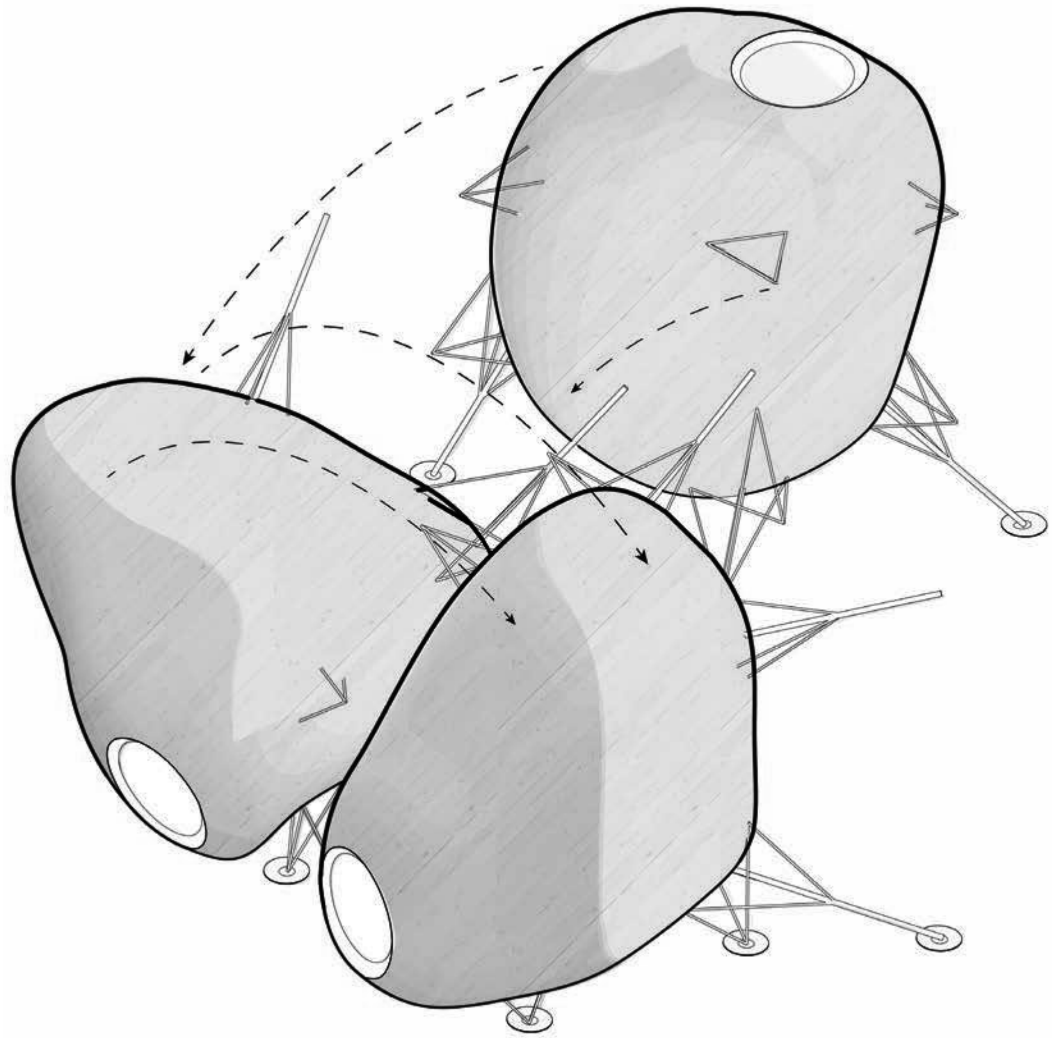

Figure 5. Final Drawings by Keygan Sinclair

exercises, in this case, the first, which was the summer, and the next two, the spring-fall and winter orientations, you can start to get a sense of how spaces push and pull are expanded and contracted in emergent ways. While the formal outcomes of this process are compelling, the process is the most important aspect. Design is driven by a generative and dialectic cyclical process that will produce a more emergent and nuanced form. When the dialectic nature of the process is driven by environmental forces, new and compelling systems-based architecture can emerge.

ENDNOTES

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