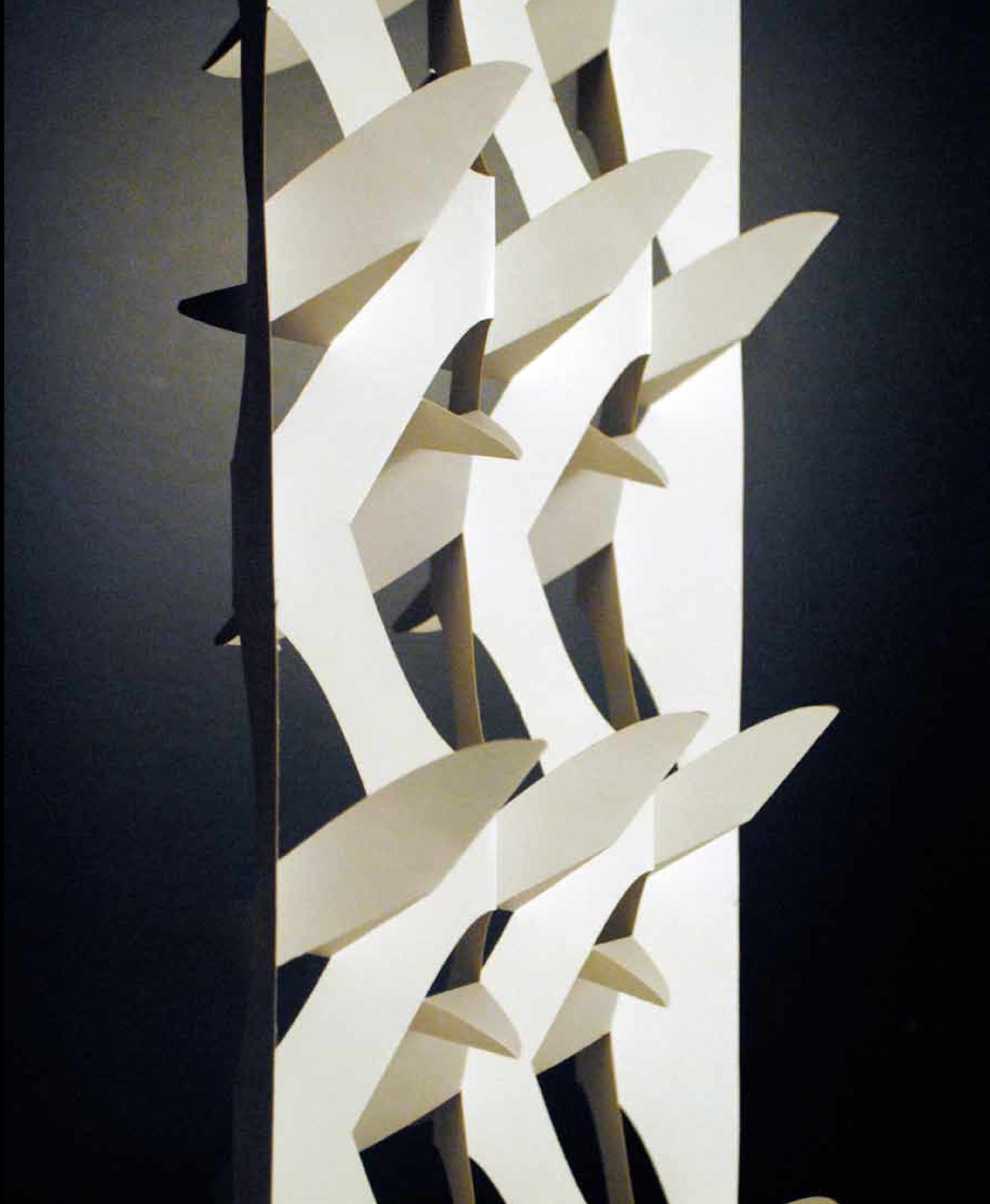
SHAPING LIGHT

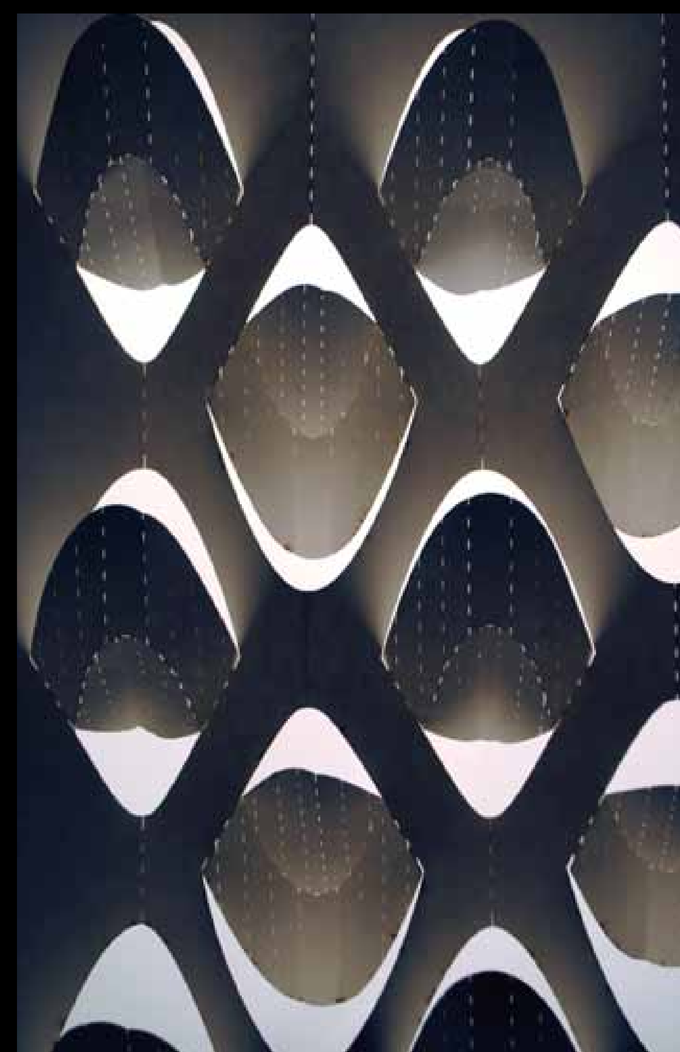
Report by **Abraham N. Rodriguez**
Supervised by **Nancy Yen-wen Cheng**
University of Oregon

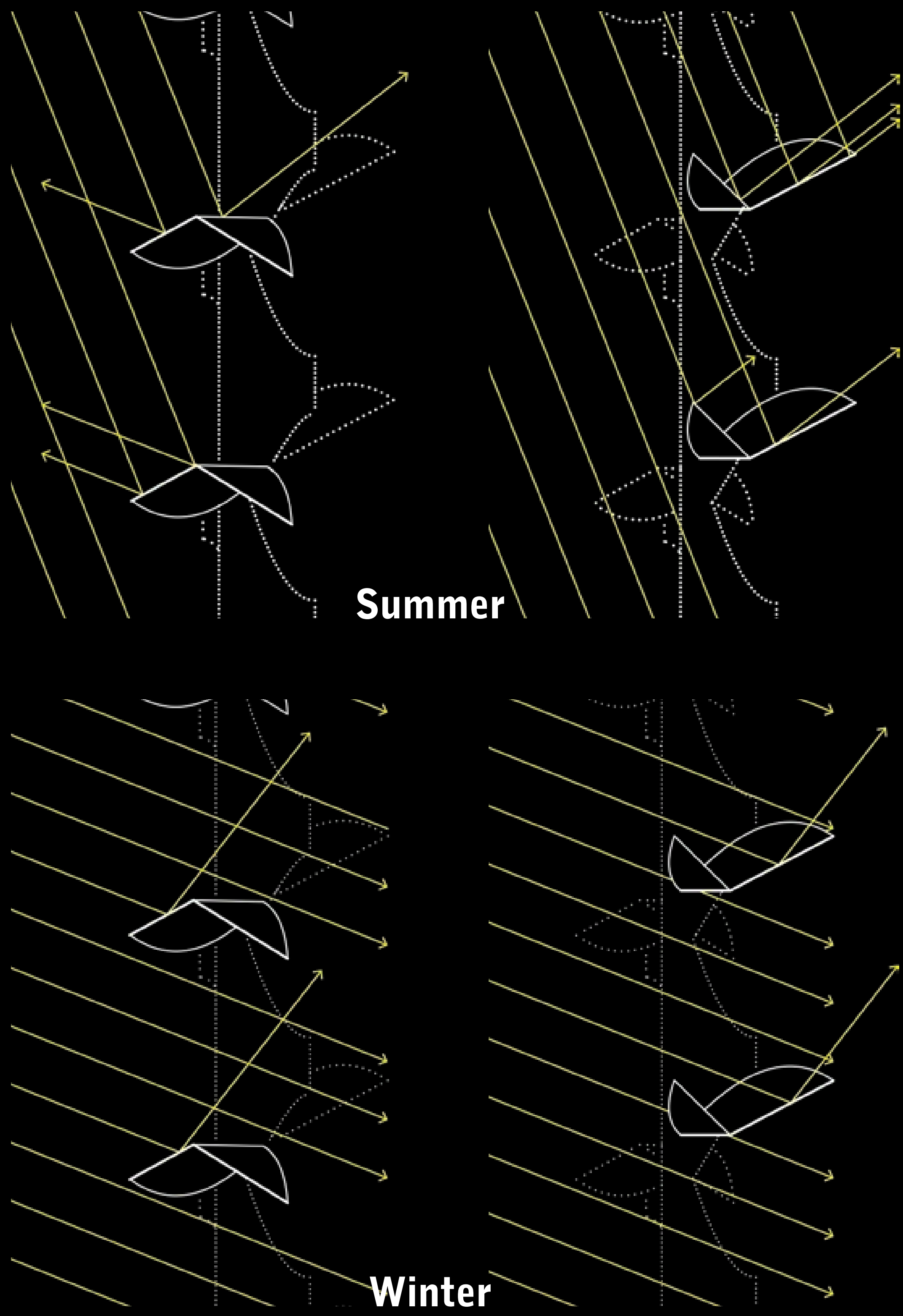
How can simple folds and slits transform a 2D sheet into a compelling 3D light modulator? Using these folds and slits to adjust the structure we can shield or bounce light. The purpose of this study is to explore how kinetically adjustable surface structures can create beautiful sunshading screens that modulate heat gain and light levels in response to changing seasons.



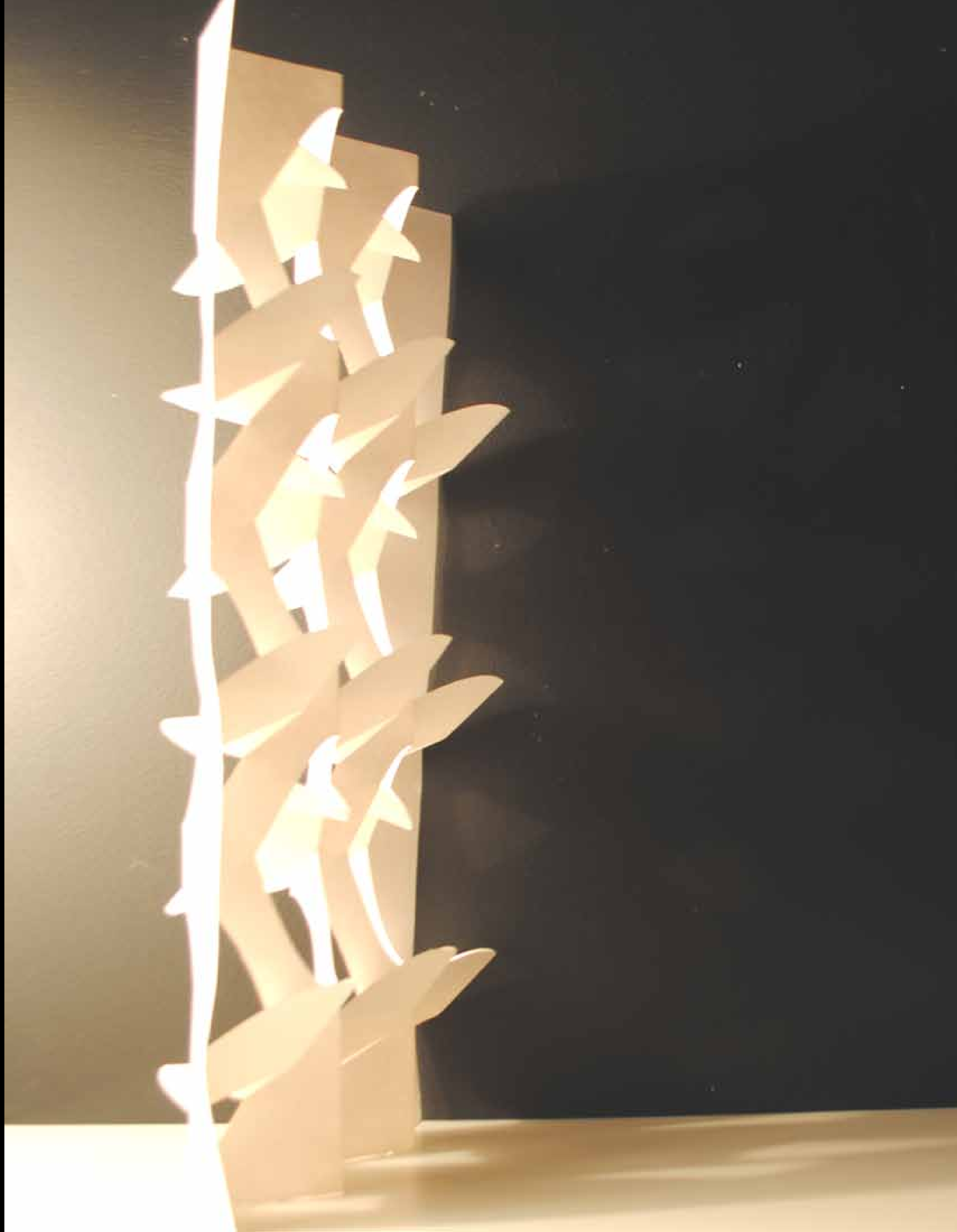
Geometric Development

This study started with a slit and folded opening that bounced light as its diagonal folds were compressed into a pocket. We created variations of this flower petal-like pocket, studying the effects of curved folds and aggregation patterns on light and shadow effects. After testing a variety of prototypes, we settled on an accordion-pleat pattern that provided the best possibilities for a room-size kinetic modular system while still maintaining an interesting visual pattern. Crisp v-folds allow the surface to fully compress (more than visually compelling soft curves). Vertically flipping the cut motifs on alternate convex vs. concave spines makes the petals move in the same direction so they can bounce sunbeams together. Adding a secondary inverted fold within the petal creates a scoop that bounces more light, gives the alternating motifs more visual similarity, and reinforces the original fold structure.





Folded petals reflect high-angle summer light and admit low-angle winter light. See Köster (2004).



Modeling Daylighting Effects

After selecting our test pattern, a daylighting model was built in order to test the screens' thermal and visual performance in a south facing classroom. Our model is based on room 451 of the White Stag Block, a University of Oregon's satellite building in Portland, OR. The model created took into account the reflectivity of the rooms surfaces and materials, the size and placement of its window openings, the placement of furnishings, and the room's structure. As the climate of Portland, Oregon includes sunny, dry summers and overcast wet winters, we examined the screens under both direct sun and diffuse sky conditions.

To test the differences between the screen when compressed versus when taut, two screens were created using identical geometric cutouts. The screen when compressed is designed to allow in more light, while the stretched screen is designed to block sunlight. (Since stretching the compressed screen shown in the photos would require curving the screen so it could extend perpendicularly from the window, a shorter screen was used.) We used the angles of a heliodon to test the screen's shading effects at hourly intervals during three seasons - summer solstice, equinox, and winter solstice. Our photos and videos show that the shadow patterns change in a dramatic way with sun movement, particularly when the sun is low.

To simulate the the diffused light distribution of an overcast day, additional testing was done under a mirrored-box artificial sky that simulates the diffused light distribution of an overcast day. Light sensors allowed us to compare daylight factors for the two configurations and see the light fall-off with depth of the room.

Room 451 of the White Stag Block

Heliodon Setup

Artifitial Sky Testing

SCREEN COMPRESSED

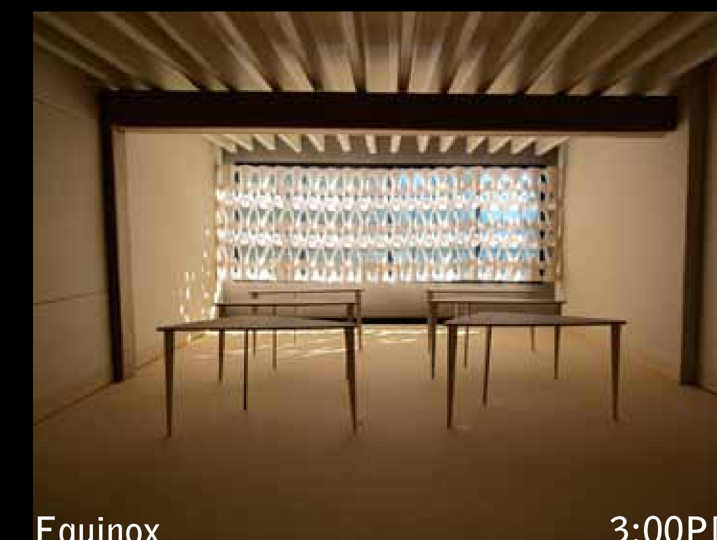

Summer Sosltice 9:00AM


Summer Sosltice 12:00PM

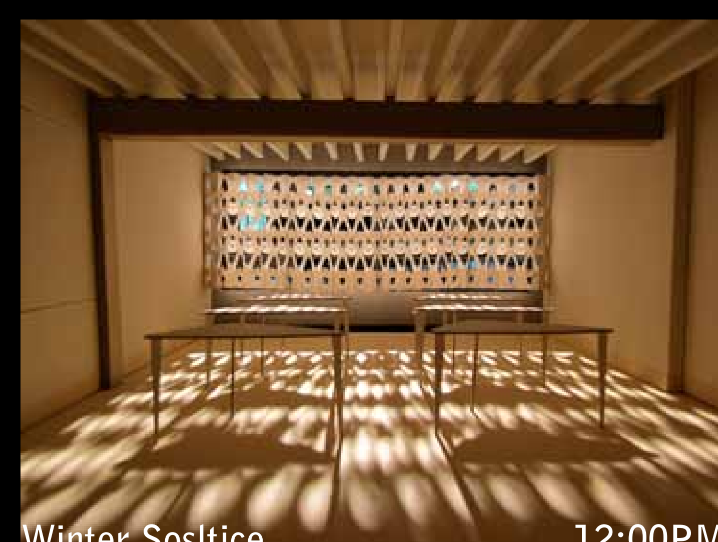

Summer Sosltice 3:00PM


Equinox 9:00AM


Equinox 12:00PM


Equinox 3:00PM


Winter Sosltice 9:00AM


Winter Sosltice 12:00PM


Winter Sosltice 3:00PM

SCREEN TENSIONED


Summer Sosltice 9:00AM

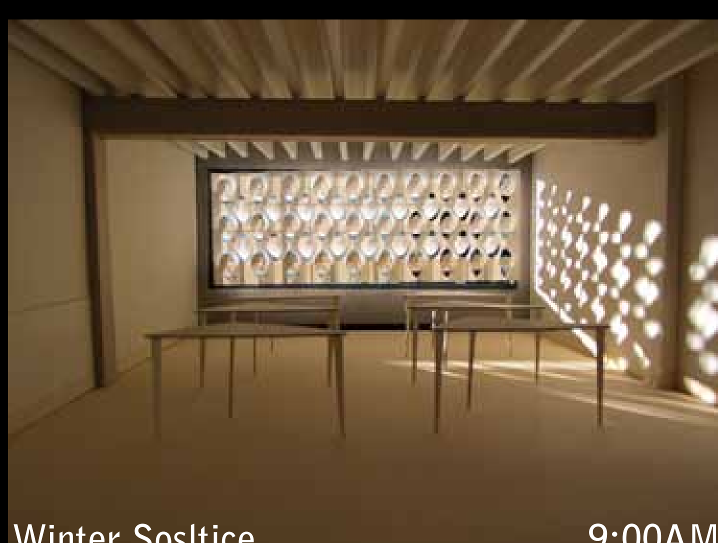

Summer Sosltice 12:00PM

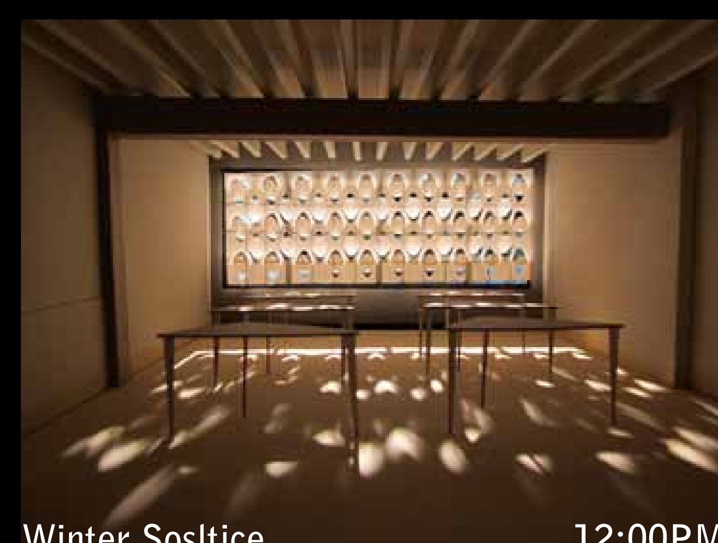

Summer Sosltice 3:00PM

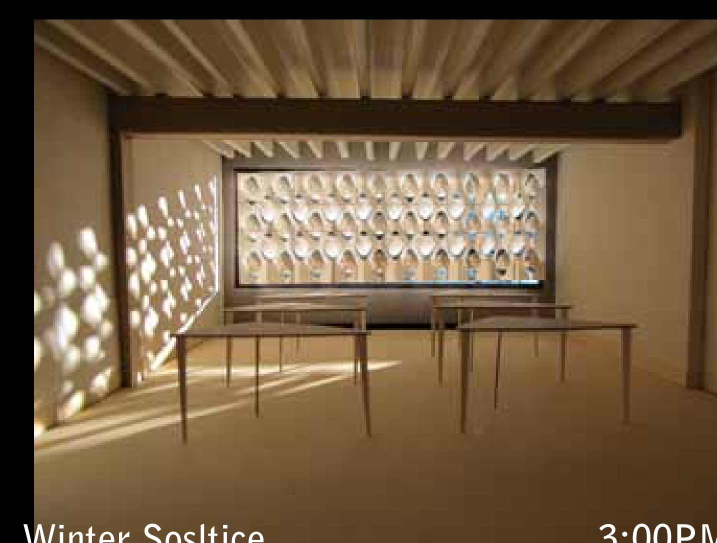

Equinox 9:00AM


Equinox 12:00PM


Equinox 3:00PM


Winter Sosltice 9:00AM


Winter Sosltice 12:00PM

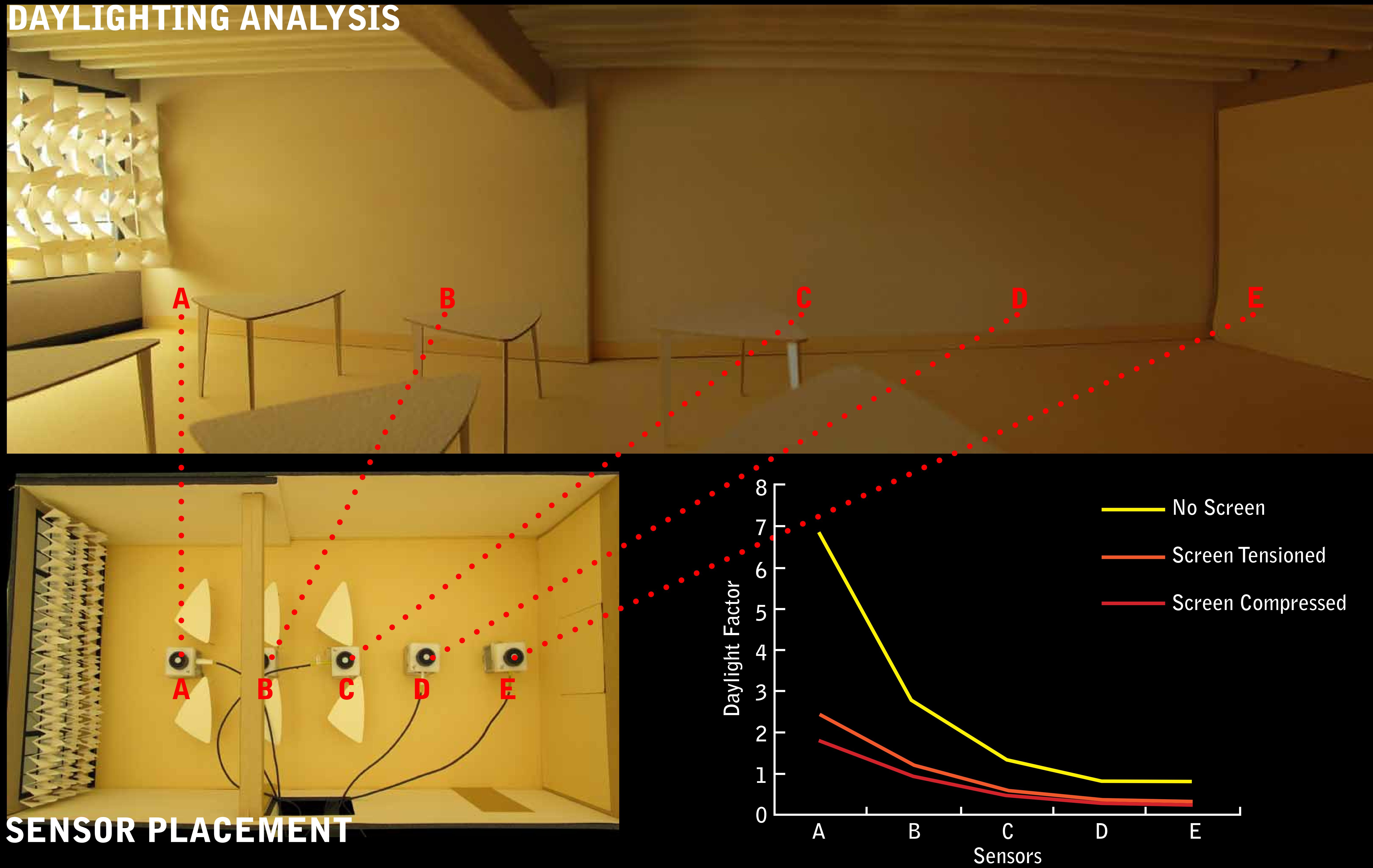

Winter Sosltice 3:00PM

SCREEN HANGING/STORAGE EXAMPLES

Screen Tensioned with Projection Screen

Screen Compressed for Storage

As previously stated, since stretching the compressed screen would require curving it along the wall, we used a shorter screen to show the screen in tension. Shown here are images of how the single tensioned screen would look with its excess length along the side wall; with a projection screen lowered, or compressed fully to uncover the window.


DAYLIGHTING ANALYSIS
A
B
C
D
E
SENSOR PLACEMENT
A
B
C
D
E
8
7
6
5
4
3
2
1
0
Daylight Factor
A
B
C
D
E
Sensors
No Screen
Screen Tensioned
Screen Compressed

DIFFUSE LIGHT

Screen Compressed

Screen Tensioned

Conclusions

In the summer and equinox conditions both screens successfully shield direct sunlight, allowing some light into the front of the room, yet reducing heat gain and glare. During the winter, both screens allow sunlight to penetrate deeply into the space, with the compressed screen casting a more interesting pattern on the rooms walls and floor. The high-contrast shadow patterns would be more appropriate as visual stimulation for waiting areas, as they could distract from visual presentations or activities done in a classroom.

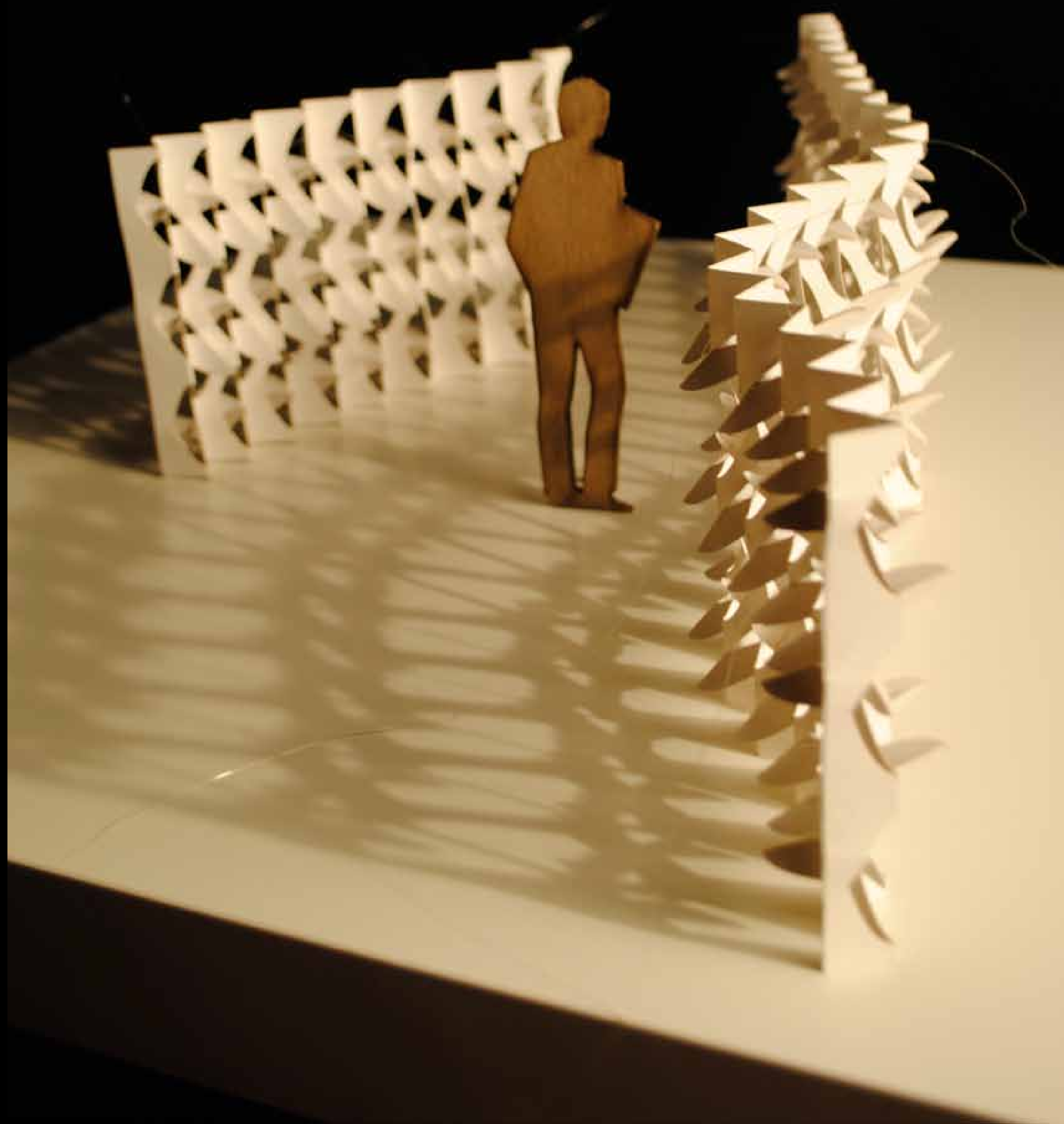
Under the overcast sky conditions, both screens block more than half the incoming light. In blocking slightly more light, the screen in Tension diffuses it more evenly. In blocking more of the view beyond, the Tensioned screen more effectively reduces contrast and creates a more visually pleasing pattern than the Compressed screen. Ultimately, the adjustable screen is much more likely to be used in the spring and fall due to the variable sunlight in the season. In the winter the screen is likely to be removed or slid aside in order to maximize light and heat gain.

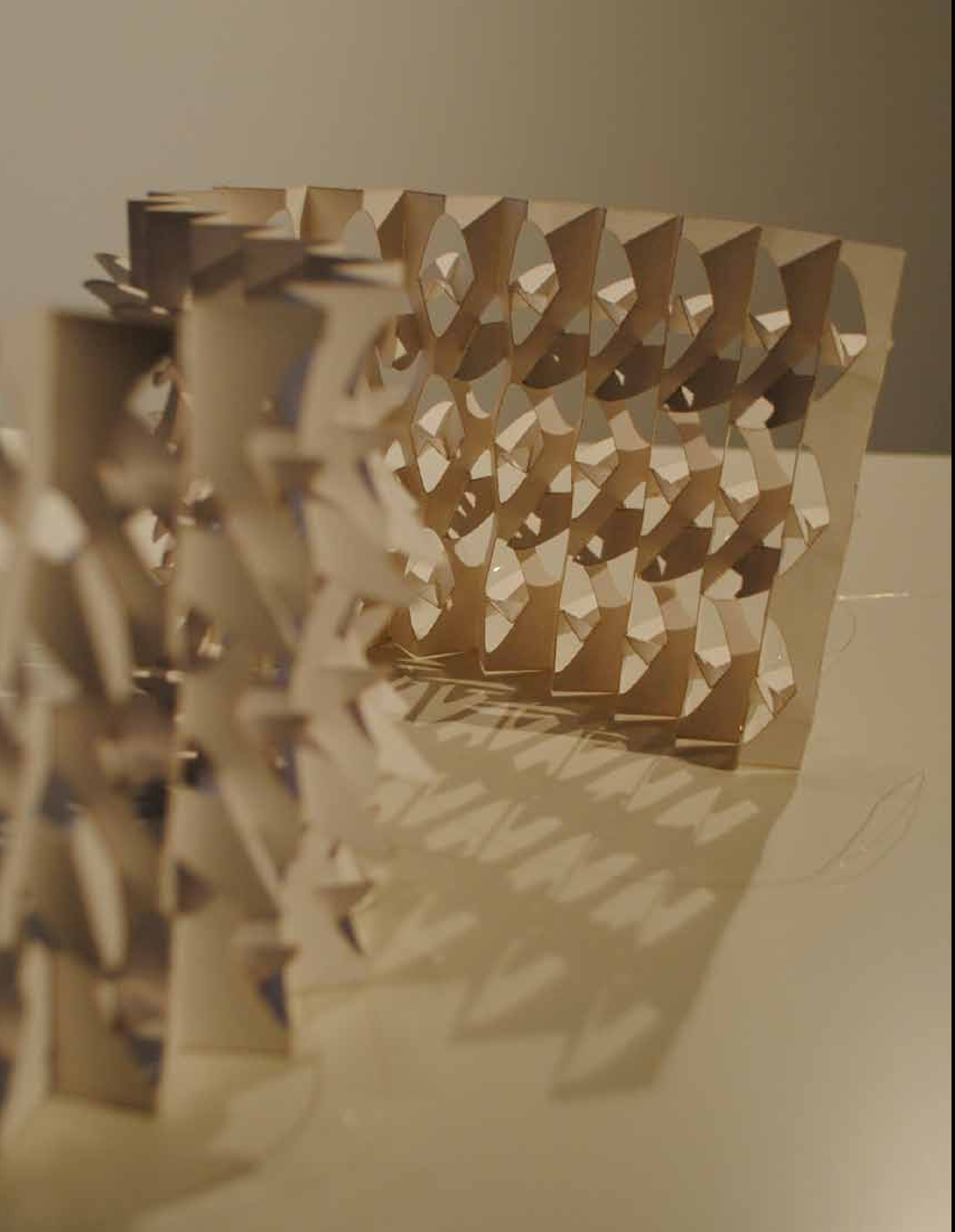
As currently envisioned, screens of this type offer an exciting possibility for efficient and visually pleasing light modulation that fits the needs of various end users. We are interested in how the aperture shape, fold pattern and mounting system could make it easy to adjust the screen for different facade orientations and functional requirements. Additional geometric optimization is necessary to bounce sunlight deeper into the space for better daylight distribution. In addition to their use as sunshades, the folded surfaces could act as aesthetically pleasing room dividers and be armatures for interactively responsive installations.

Future Possibilities

We are eager to see how much of origami's simplicity can be maintained as we scale up. Concurrently, we are researching how fiber, plastic or composite materials could meet our unique requirements of reflectivity, opacity, flexibility and durability. Procedures for cutting, folding, fabricating and mounting are dependent on these material characteristics and change dramatically with scale. (i.e. lasercutting for prototyping, die-cutting for mass production). While habitable structures will always require connections and components, we are interested in making folds integral to the sheet and maximizing the dimension of the contiguous sheet. We would like to find ways that the screens could be automatically cut from a large roll, folded over a jig, assembled and installed. As in Issey Miyake & Dai Fujiwara's APOC - A piece of cloth project (Scanlon, 04) we could custom manufacture the material for the final 3D product. The material could woven, printed, embossed or overlaid with patterns of rigid ribs, resilient and reflective petals, and embedded tendons. (McQuaid, 2005).

Outside of the specific screen product, we want to define a digital + physical pipeline for development and testing of shading devices that addresses performance criteria and maximizes creative opportunities with material experimentation.We need a fluid path between playing with material form, generating digital models and analyzing thermal and lighting characteristics. Along with easy physical to digital translations, we need accessible, interoperable software for both accurate measurements and compelling visual representation.





Bibliography:

1. Guzowski, Mary (2010). "Carbon Neutral Daylighting Design." *The Carbon Neutral Design Project.* Retrieved from http://www.architecture.uwaterloo.ca/faculty_projects/terri/carbon-aia/strategies1e2.html
2. Hauer, Erwin. (2004). *Continua: Architectural Screens and Walls.* New York, NY: Princeton Architectural Press.
3. Energy Studies in Buildings Laboratory, University of Oregon School of Architecture and Allied Arts (2008). *Daylight Model Construction Guidelines.* Eugene, OR.

Works Cited:

1. Köster, Helmut.(2004) *Dynamic daylighting architecture : basics, systems, projects.* Boston: Birkhäuser.
2. McQuaid, Matilda, and Philip Beesley (2005). *Extreme Textiles: Designing for High Performance.* New York, NY: Princeton Architectural Press.
3. Scanlon, Jessie (2004). Wired 12.04: Seamless. *Wired Magazine.* Retrieved from http://www.wired.com/wired/archive/12.04/miyake_pr.html

Shaping Light Researchers:

Nancy Yen-wen Cheng; Lead Researcher

Research Assistants
Sina Meier
Jeffrey Maas
Nicolaus Wright
Geoff Sosebee
Jerome Alemayehu
Abraham N. Rodríguez

Acknowledgements:

Thanks to Jerome Alemayehu for materials research and assitance in the design and construction. Special Thanks to Jason Stenson; Energy Studies in Buildings Laboratory- University of Oregon.

This project has been funded by the University of Oregon School of Architecture and Allied Arts' Summer Research Award (2011) and
the Jerry and Gunilla Finrow Architecture Studio Award (Fall 2009)

Nancy Yen-wen Cheng: nywc@uoregon.edu
Abraham N. Rodriguez: abrahamn.rodriguez@gmail.com