V.E.I.L.S. | Performance Based Case Study

NATHAN HOWE
Kansas State University

ABSTRACT

The architecture profession is evolving to take on more scientific methods of testing and prototyping performative assemblies. This is also occurring within the academy creating a synergy between computing, simulation, data collecting, digital fabricating and design. This paradigm shift is simulated within the case study this paper presents. The project asked for students to design and implement a screen for the Dean of our college. His southern-exposed windows recorded temperatures of 120°F at his desk on a typical sunny winter day. This project, Variant Exposure Intelligent Light Screen (V.E.I.L.S.), was designed and built to passively correct this problem. The students, armed with fortitude, energy and a beginning knowledge of software, learned to collect and interpret data, hypothesize solutions, then simulate and test these hypotheses both physically and virtually, fabricate the design, and finally evaluate the design post occupancy.

This case study brings to bear design as a problem-solving initiative where careful study of the problem is choreographed within a tight time constraint, small budget, clear performance parameters, feasible construction methods and aesthetic drivers. It is this paper's theory that learning by doing can be the best way to gain knowledge and this project became a microcosm of many real world concerns. As technology advances, the architect has to strike a balance between traditional methods of design and construction while also engaging in simulation and digital fabrication tools which can help create better performing buildings. This paper will discuss how architecture education can formulate and empower students with the knowledge to engage in this new world.

KEYWORDS

data, simulate, cnc, digital, fabrication, passive, solar, screen, performative, studio, design/build

INTRODUCTION

Innovation is a development that people find useful or meaningful. To be innovative, architects – themselves – must become more responsive to their users and environments. In other words, they must incorporate feedback from their physical and cultural contexts rather than relying solely on conventional analytical or internal processes of development…from design to construction.
– Ali Rahim, architect[1]

Whether one agrees with Rahim's approach to architecture, this quote has embedded within it a deeper responsibility for architects today. With phrases such as *responsive to users and environments* and *incorporate feedback,* it is clear that a rethinking of practice as usual is in order. As educators, this also stimulates a shift in ways of teaching. How do these objectives become part of teaching the next generation of architects? How do we give them the tools which enable them to work within a model where formalistic, aesthetic, and poetic meaning is not enough? They are going to design in an architecture profession where one has to become responsive in a legitimate way to climatic issues of form, material and space. This is a large task and one with multiple answers. There is no magic bullet, yet there is a responsibility as an educator to participate in helping the next generation of architects achieve an understanding of how to play an active role in this discussion.[2]

This shift in design thinking to one of innovation has been steam-rolling through architecture for years. However several convergences make this a most interesting time to be educating the next generation of designers. The computer, often accused of seducing the profession with the possibility of change, has finally reached the point where it can function as more than an efficiency tool, but a true design tool. This is due to the combination of processing power reaching a critical level where complex associative geometries can be handled by the hardware and the advent of software being designed to readily handle simulation and information based on geometry and environmental data.

This is where performative architecture comes into the conversation. Performative architecture is the measure of how the economics, social, cultural, contextual, form, assemblies, and materiality of a building measures against its environmental, acoustical and structural systems.[3] Performative architecture allows for the architect to be more innovative, more responsive to their users and environments, and formal decisions are closely tied with scientific testing methodologies.

This synergy of advances in computation, social, and environmental awareness finds education today teaching in an arena where performative measures become more relevant and possible to test theory and practicum. The Variant Exposure Intelligent Light Screen (V.E.I.L.S) project demonstrates how a team of students with little to no prior knowledge of simulation software, data collection and basic fabrication skills can take on a design/build project where the building has failed and an intervention is required. This project holds itself as an example of how students are best taught through doing, where collaborative work allows for collective expertise to be brought into the design process and scientific methodologies are not shied away from, but embraced.

STUDIO | THE CHALLENGE

The third-year Spring studio in our curriculum is focused on tectonics and contextual place making issues. To further student innovation in considering specifically the ideas of making inherent in the tectonic conversation, I have used small design/builds to teach parametric methodologies and algorithmic thinking. These studies then take this abstract thinking and implement them within the design/build process. The first of these design/build projects was *Dripple*. This formal study created a synthesis between a parametric model and digital fabrication tools such as a laser cutter. The context used was the studio room and the performative measures were based more on atmospheric aesthetics than in any environmental issues.[4]

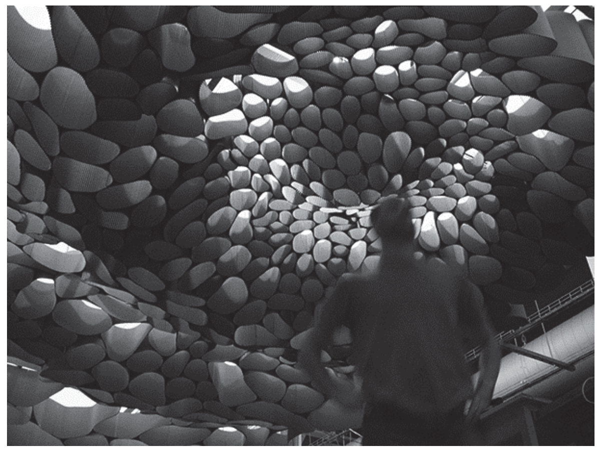

Figure 1: Image of *Dripple*, a corrugated cellular structure.

The success of this precursor to V.E.I.L.S set the stage for what the Dean of our college challenged us with next. The Dean occupies a south-facing office located in our turn-of-the-century limestone edifice, Seaton Hall. The single-pane, wood frame windows provide little to no protection from the thermal conditions outside. He often needed to pull his blinds and turn on his air conditioning window unit in the middle of winter to keep from baking on a sunny day.

This new project would truly push how the students worked within a team and their knowledge of design. Whereas *Dripple* had very few parameters driving it other than a formal construct, this new project would have to perform on many levels. The project had to deal with issues of climate, constructability, context, economics, short time frame, preservation, and aesthetics on a historical building. *Dripple* appeared suddenly like child's play in comparison.

In any endeavor to build, one has to come to terms with three forces immediately: economics, time, technology. These three forces drive many decisions and a good designer or design team must balance this triad. In this case, the Dean was funding the project and had a limited but reasonable budget. However, the other two, time and technology, were going to be true tests. The warm-up would run from the beginning of the semester on Wednesday and wrap up 12 days later on the following Monday, designed, built and installed. Technology was also a huge unknown. This was the first time I would meet the students, so their experience with construction was unknown. The hope was that a few would at least have some shop experience. The college had recently purchased a CNC mill[5], so I knew I would be teaching the students to interface with this technology and this would hopefully be the saving grace during execution.

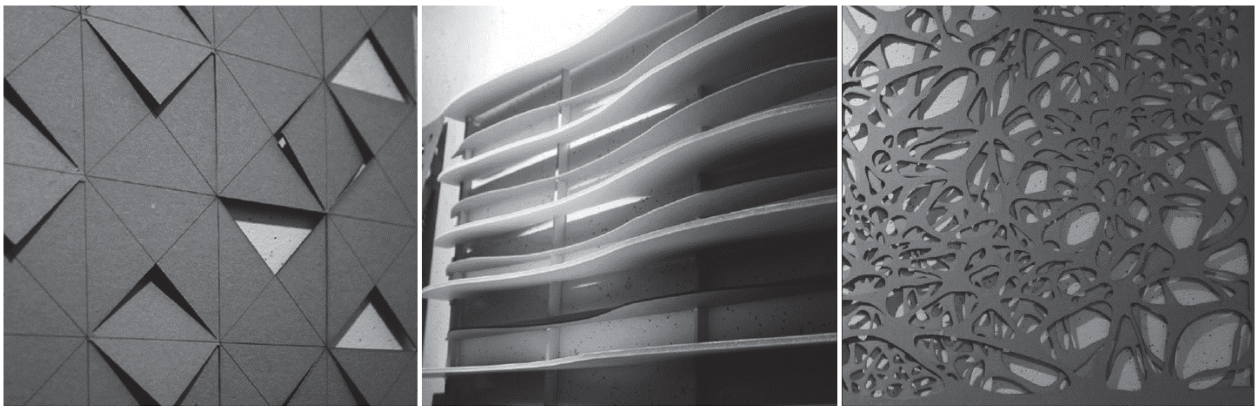

Figure 2: These images show the prototypes developed by the three teams: perforated, louver and layering.

WEDNESDAY | ORGANIZED

Undaunted by the difficulties of the project, the students were immediately on board. The desire to be a part of building something is inherent in this generation of architecture students. Throughout architecture schools, more and more design/build programs have emerged brought on as much by the growing faculty with construction expertise as the students' desire to build.

It is important in design/build projects that each student has a task which is interdependent amongst others in the team. This interdependence creates a sense of unity amongst the whole and a sense of accountability.[6] Each student was assigned a team or task they would need to perform outside of their design team responsibilities. There were fifteen students. From these, two students were elected to project manager roles: one in charge of fabrication, the other in charge of research and development. Three other students were placed in charge of data collection and assimilation, three on shop fabrication, two on drawings preparation and organization, two on documentation, one on digital recording, and two students became our utility players, essentially stepping in on any team to help as needed. These two students became instrumental as the ebb and flow of the project workflow required demands at different moments on the various teams for these students to step in and relieve pressures.

Once organized, we set up a series of data loggers in the Dean's office to begin collecting data on lumens and temperature. Then the students began to research case studies and to individually design possible solutions. They were asked to keep in mind the following criteria: solar performance, budget, constructability, pigeon proofing, wind resistance and aesthetics. They also had to bear in mind to only use materials which were readily available locally and construction techniques which would take advantage of our CNC equipment.

FRIDAY | PROTOTYPES

By the next studio meeting, each student presented research findings and a design prototype. From the solutions we began to categorize strategies into three types: perforated, louver and layering. Design teams of five students each emerged with a mix of shop and analytical skills distributed evenly amongst the teams. Each team focused on one design strategy and prepared a design proposal to present on Monday, when the studio would choose one design for development and prototyping.

Solar performance was of primary concern with this design. This meant we had to come up with a methodology to test our designs for performance. For Monday's pin up, each team would have a working model at 1-1/2" scale for analysis and testing. The shop team would build two boxes with the window opening representing the office dimensions at that scale. We would use our data loggers to record lumens and temperature over the course of a few hours of the day testing each prototype on the boxes. This data would measure the performance of each design and would be one factor for our decision-making process.

Each team prepared an initial cost estimate of the project as designed. The teams were also to prove a concept for constructability. These two factors asked the students to consider things they had never had to worry about. V.E.I.L.S.' scale provided the ideal setting to give students the "real world" issues of practical matters. In academia students rarely are exposed to financial restrictions, however this factor becomes a necessary concern in design/build projects and, although limiting, can provide an excellent educational outcome.

MONDAY | DESIGN RECKONING

The three team prototypes--perforated, louver and layering--were measured on solar performance, budget, constructability, pigeon proofing, wind resistance and aesthetics, and generated a long discussion on the pros and cons of each design proposal. Since constructability and budget were primary concerns, each team had chosen an aluminum sheet metal for the majority of its construction. Aluminum had advantages as it would not need any further protective coats, and our CNC mill could be utilized for the cutting. Use of any other standard sheet metal would have required outsourcing, adding unknowns of scheduling and expense.

Each design was put to the test in our scaled boxes with a heat lamp. Surprisingly, each one performed reasonably well. The layering design (Figure 2, right) was the only one to spike in lumens and temperature because the pattern had too large of openings in certain areas.

A summation of the discussions showed the perforated scheme (Figure 2, left) was the most economical due to its simplicity, although its aesthetics were underwhelming. The perforated scheme needed more openings (it got too dark in the office), yet the effect of light patterning within the office was seen as an aesthetic bonus. The diamond pattern of light was not the desired pattern, however much like a Middle Eastern stone shading screen, the perforated scheme created a geometric pattern of light which was beautiful.

The louver design (Figure 2, center) performed the best in modulating heat and lumens, yet was over budget due to the amount and depth of the louvers and had much to work out with construction details, wind resistance, and pigeon-proofing. Since this project was a short warm-up, students were asked to have the answers or not. There was not enough time for them to design and resolve key technical details later. The teams had been asked to prove a concept for constructability and if none was offered, this weighed heavily. In analysis of aesthetics, the horizontal louvers' appeal was completely externally driven, and was criticized because it virtually disappeared when viewed from inside the office.

The layering design won out on aesthetics. Its layered pattern of various densities created a beautiful object from the exterior of the building but also transformed the interior with a dappled light pattern. Unfortunately it was over budget, due to the three layers of aluminum necessary to create the effect.

Through this prototyping process, the students realized they could create something which would not only perform, but would use light to transform the interior atmosphere of the office. Thus the perforated design won the day. The students learned the importance of considering the internal as well as external aspects of design and felt they could modify the pattern to better deal with the aesthetics on the outside while creating beauty on the inside.

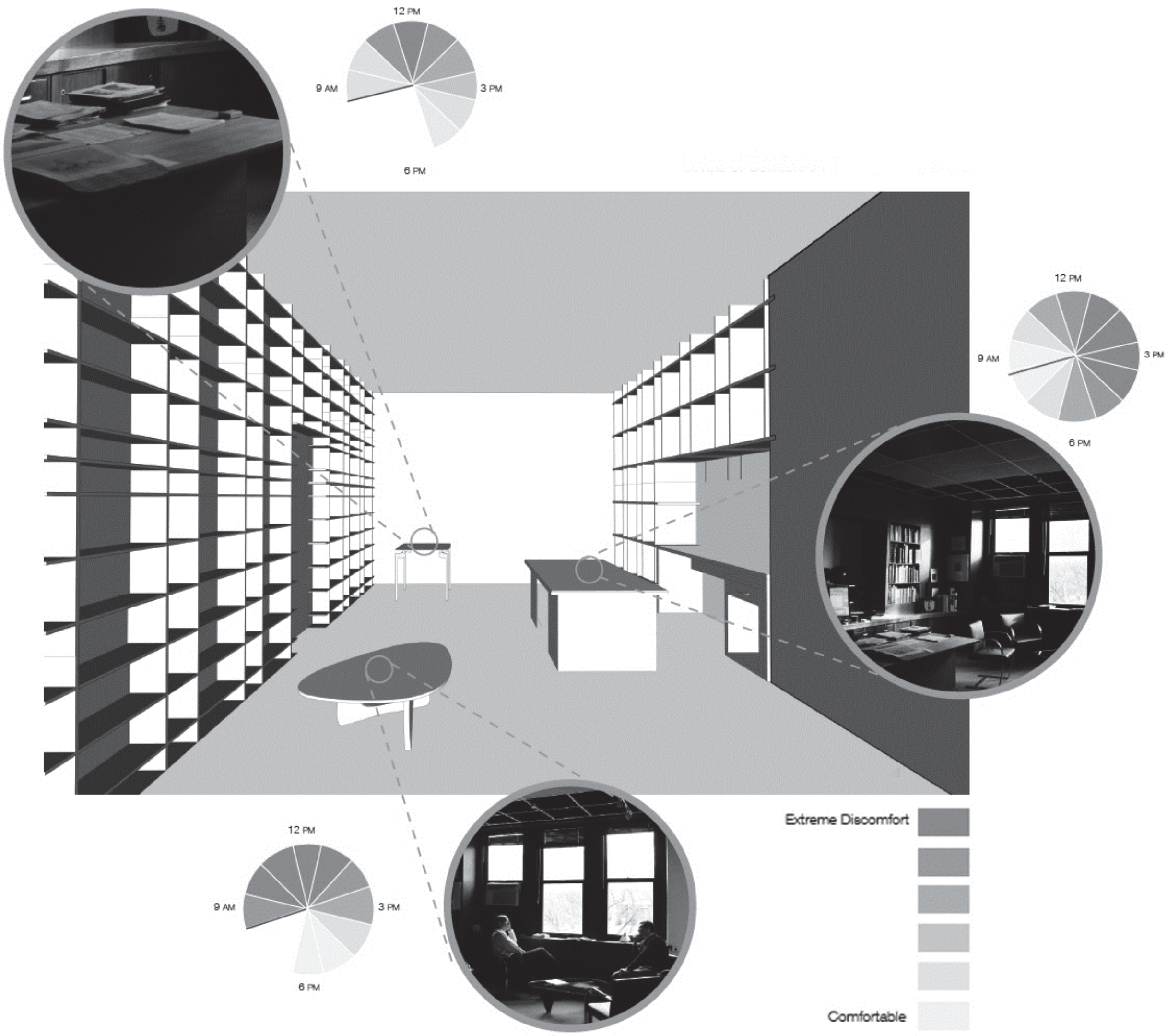

Figure 3: In this image the viewer is replacing the Dean's windows. The darker gradients show the levels of discomfort during a day. The assumed comfortable temperatures were 69-73°F with the darkest gradient reaching upwards of 120°F on the desk surface.

"...We were born of light. The seasons are felt through light. We only know the world as it is evoked by light, and from this comes the thought that material is spent light. To me natural light is the only light, because it has mood—it provides a ground of common agreement for man—it puts us in touch with the eternal. Natural light is the only light that makes architecture [A]rchitecture..."[7]
-Louis Kahn on the Kimbell Museum.

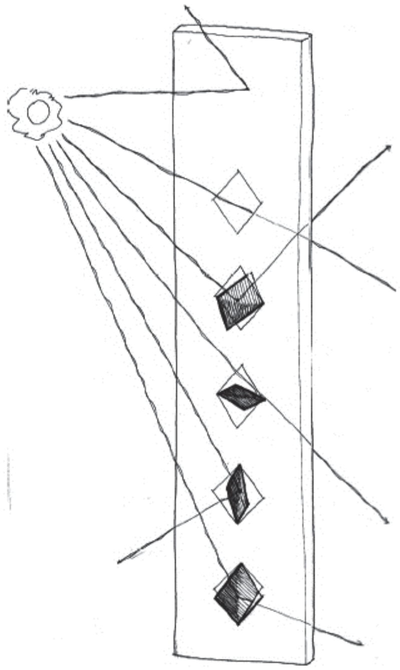

Figure 4: This diagram shows the possible orientations of the flaps rotating on a vertical or horizontal axis.

MONDAY TO SUNDAY | V.E.I.L.S.

Once the design direction was chosen, organized chaos ensued. The fabrication team began working on a mock-up of a steel frame which would interface between the stone façade and the aluminum screen panels. The collected temperature and lumens data required further analysis, and working hypotheses needed to be formed and tested. A team was created to work on a parametric model to better control the perforations. A prototyping team was formed to take the various patterns created by the parametric team to prototype physical models and run lighting simulations in the computer.

Data

As stated before, we used sensors to track light amounts in lumens and temperature. The diagram in Figure 3 shows the view from the Dean's window wall and best describes the average of our results on a typical sunny day in winter. We placed sensors in the room according to areas of use: the Dean's desk, his lounge seating for meetings, and a table in back for layout space. We continued to use these areas for testing and also to analyze and simulate approaches for controlling heat gain and glare. This study showed that on a typical 30-40°F winter day, temperatures in the Dean's office would soar up to 120°F. It showed significant discomfort throughout the late morning and afternoon in the primary spaces the Dean would occupy during these times.

Diamond Logic

The simple geometry of the diamond form was chosen for the perforations. To provide varying degrees of porosity, some of the forms would not be routed completely out. Much like the screen designed by the Virginia Tech entry into the International Solar Decathlon in Madrid,[8] the geometry was cut leaving two tabs of material on either side, allowing the "flap" to be rotated into a specific position. This flap could be oriented along either a horizontal or vertical axis (Figure 4) to deflect or reflect light as desired.

To further link the pattern to the context, we aligned our grid of diamonds to the limestone courses at the window opening. Three rows of diamonds established each course.

Pattern Logic

"The new architecture will not be about style, but rather about substance—about the very methods and processes that underlie making."
- Kieran, Timberlake[9]

Although aesthetics were never neglected in this endeavor, analytical methods and processes were the underpinnings of the design. These processes were affected by our studies of light penetration: the amount of light which needed to be blocked to keep heat gain to a minimum and the program areas within the office where glare would be an issue.

Through careful observation and data analysis, the students concluded that we should divide the windows into a grid and that each grid would be evaluated for how light would be controlled (Figure5). This also aligned with the denser grid we had previously established in regards to the limestone coursing and rows of perforations. Three courses of limestone equaled the height of one cell in the grid.

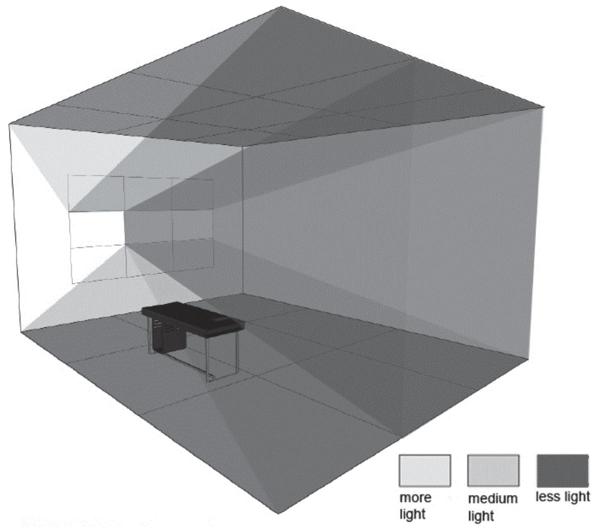

Figure 5: This diagram describes the distribution of light levels throughout the office. The white zone in the middle left panel was where the air conditioning unit was housed.

Parametrics

Parametric design systems are introducing whole new modes of design. With object-oriented models, environmental data analysis, and building simulation, the type of control and valuable information available to the architect has exploded. With this outburst, the designer must learn to be facile in this information age. During the first phase of this project, when the students were getting organized and fleshing out design proposals, I did several one-hour workshops on Grasshopper[10], a visual script explicit logic plugin for Rhino[11]. These workshops demonstrated a few concepts of how to better control and iterate geometry.

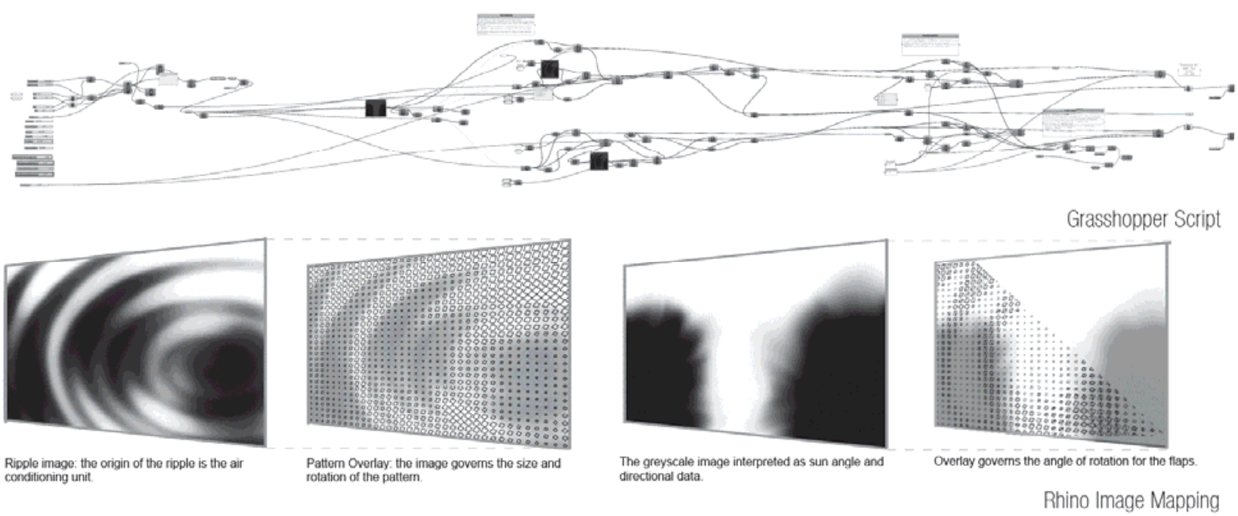

Figure 6: These series of diagrams show the Grasshopper script in concert with the various image samples controlling scale and rotation of the perforations, and orientation of the flaps.

From these workshops I learned who on the team gravitated toward this logic and they became the parametric team. This team took the logic of previous analysis and worked up scripts to better control the perforated pattern and to orient flaps for deflection and reflection of light.

The underpinning parametric logic should remain simple however complex the script, especially for students just beginning to use such advanced tools. After many iterations the following inherent logic was used, which allowed the students to build a script more easily. Given the zone logic shown in Figure 5, we found that the best way to control each aperture's scale and rotation, and flap axis of rotation diagrammed in Figure 4 was to use the image sampling component.

Image sampling in Grasshopper allows for an image to be overlayed across a surface, in this case the window opening. This greyscale image is then evaluated by a matrix of points predetermined by the grid we had established using the limestone coursing. For each point the image sampler would evaluate the black value within the image. If there was black, the component would give a value of 0, 50% black = 0.5, pure white =1, etc.

In Figure 6, the image on the far left represents the scale and rotation of the diamond geometry. The logic dictated that as the image gradated from white to black (black representing less light penetration desired), the diamond was scaled down. The image also controlled the rotation of the diamond, giving the overall pattern fluidity.

Figure 7: These diagrams are oriented looking in through the window wall. The top image represents one of our first simulations, where some serious glare would be felt near the desk (lighter area). The bottom shows the final design where light is distributed evenly throughout the office.

We also used an image sample to dictate which tabs to leave on the flaps, the horizontal axis or the vertical axis. One will notice the stark black and white in the right image in Figure 6 with little to no gradation between the extremes. The reason for this was we only needed a binary answer since there were only two possibilities, horizontal or vertical orientation. It was noted that the upper row of the grid in Figure 5 wanted to reflect the light up to the ceiling. In Figure 6, the white in the third image represents keeping the tabs on the horizontal axis allowing us to rotate the flaps accordingly.

Simulation

Once we had established the logic of how light would be redirected given the grid of zones, we needed a way to test our hypothesis. We used 3dsMAX's[12] built-in lighting analysis tools to analyze design proposals. Many students were not aware the tools were readily available, and this became yet another "teachable moment" in the process. The advanced nature of the software made this testing a simple task, and was a critical part of the final design process. The parametric team was able to hand off various schemes for simulation, and a feedback loop was created where decisions were being made on performance measures.

"'Versioning' is an operative term meant to describe a recent, significant shift in the way architects and designers are using technology to expand, in time as well as in territory."
- SHoP/Sharples Holden Pasquarelli[13]

This feedback loop on performance analysis is exactly one of the shifts SHoP is referring to in their concept of "versioning". The students were able to see how design decisions affected space, and then were able to correct for miscues and fine tune successes. Figure 7 shows some of the light analysis simulations.

Fabrication

By Friday, the steel frames that would house the aluminum panels were fabricated and had been inserted in the window opening to check for accuracy. While in-site, they were also marked for location of bolts for install. The students designed a simple cleat and bolt connection for the install that only required two holes per side to be drilled in the mortar joints of the limestone façade. These frames were then brought back to the shop as the panels were being fabricated to check fit.

The students also finalized the design and set up drawings for milling. The design of the panel was simple with wings tabbed at the edges. These tabs would then be bent after the milling was complete. The flaps had a hook slot designed into them so they could be inserted into the frame and then slid down onto bolts. A diagram of this assembly can be seen in Figure 8. This folding at the edges would not only create a connection to the frame, but would serve to stiffen the panel and prevent oil-canning caused by the summer heat expanding the metal.

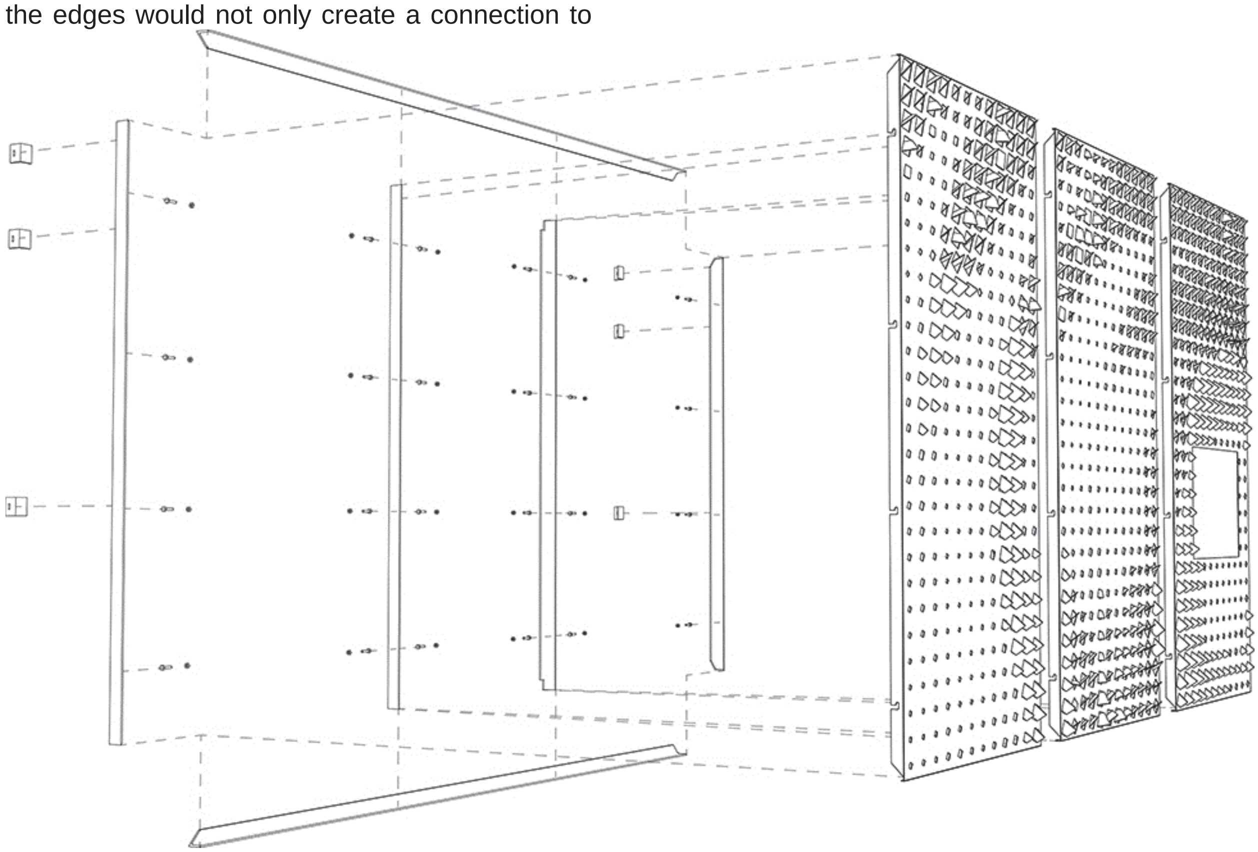

Figure 8: This assembly drawing shows how the steel frame was built with the panel's tabbed detail for installation.

Color

The final design concern was whether color should be added to the panel. It was felt that the piece would "pop" more, especially on the interior, if color was added to the flaps. This would allow the light to react with not only the sanded finish of the aluminum, but to vary across the color. The choice of orange may have been the most subjective decision made in the design process, but orange was chosen to complement the warm creamy to buttery tones in the Native Kansas limestone building. The orange within the interior of the space would also always represent the beautiful orange light of the sunset.

POST EVALUATION

The install occurred Sunday and, besides a slight increase in the air conditioning unit's aperture, it proceeded smoothly. The visual impact of V.E.I.L.S. was spectacular, as the screen created a filigree pattern of light across the office, making the windows a work of art.

From a performative perspective, the data we collected post occupancy played out our simulation perfectly. On a similar sunny winter day that was within a 5° range of our original data, the temperature fluctuation in the office was calmed to comfortable conditions throughout the day with little to no glare penetrating into the space. See Figure 9 for further confirmation.

Following the initial success of modulating the sun's penetration, however, a new concern was raised. In our brief conversations we had never discussed that once the Dean no longer needed his blinds, he would like to view the plaza outside. This is a reminder of the importance of a predesign program document, where all user parameters have been vetted. The students were up to the challenge, and not only did additional data collection of lighting levels and temperatures, but made a quick modification to the panels to provide the Dean his view from sitting height.

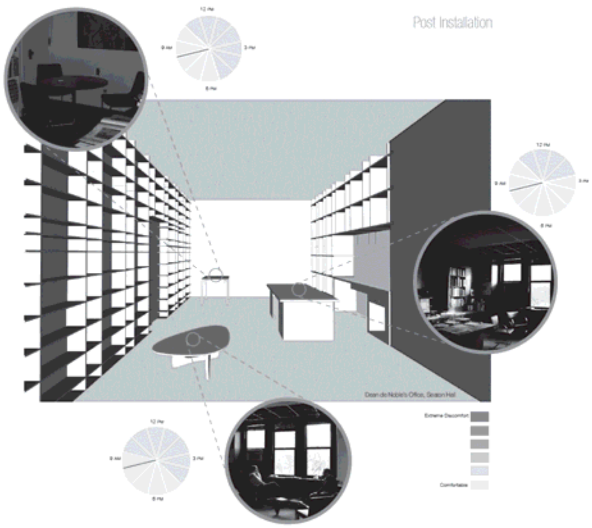

Figure 9: This diagram shows the comfort levels of temperature post occupancy. The light tones indicate comfortable temperatures whereas dark tones (none were recorded) would indicate extreme discomfort.

CONCLUSION

This project simulated many real world design complexities which add to the students' learning experience. Students learned how to design within a team environment with each member of the team being counted on for specific expertise and skills. The team considered not just the aesthetic and formal qualities of a design but its performance as well.

The shift in thinking about the performative aspects of the built environment requires the profession as well as the academy to evolve the way practice is conceived. It is through these types of projects where the next generations of architects are able to delve into these deep waters and test out the theory of parametric/performative design in theory, as well as practice. This type of model becomes an exciting test from which the dividends will help push the practice of architecture.

One final aside: How have the students who designed and built V.E.I.L.S used this new knowledge in future studio projects? Figure 11 is a project by student Max Taylor and shows his analysis and resulting parametric model to control sunlight's penetration into the One Artist sculptural museum based in New York City, designed later in the semester. His experience with V.E.I.L.S and further study in the use of parametric software allowed him to go beyond the normal exploration of tectonics and conceptual theory in a third-year studio.[14]

Figure 10: The final screen design after the modification requested by the Dean.

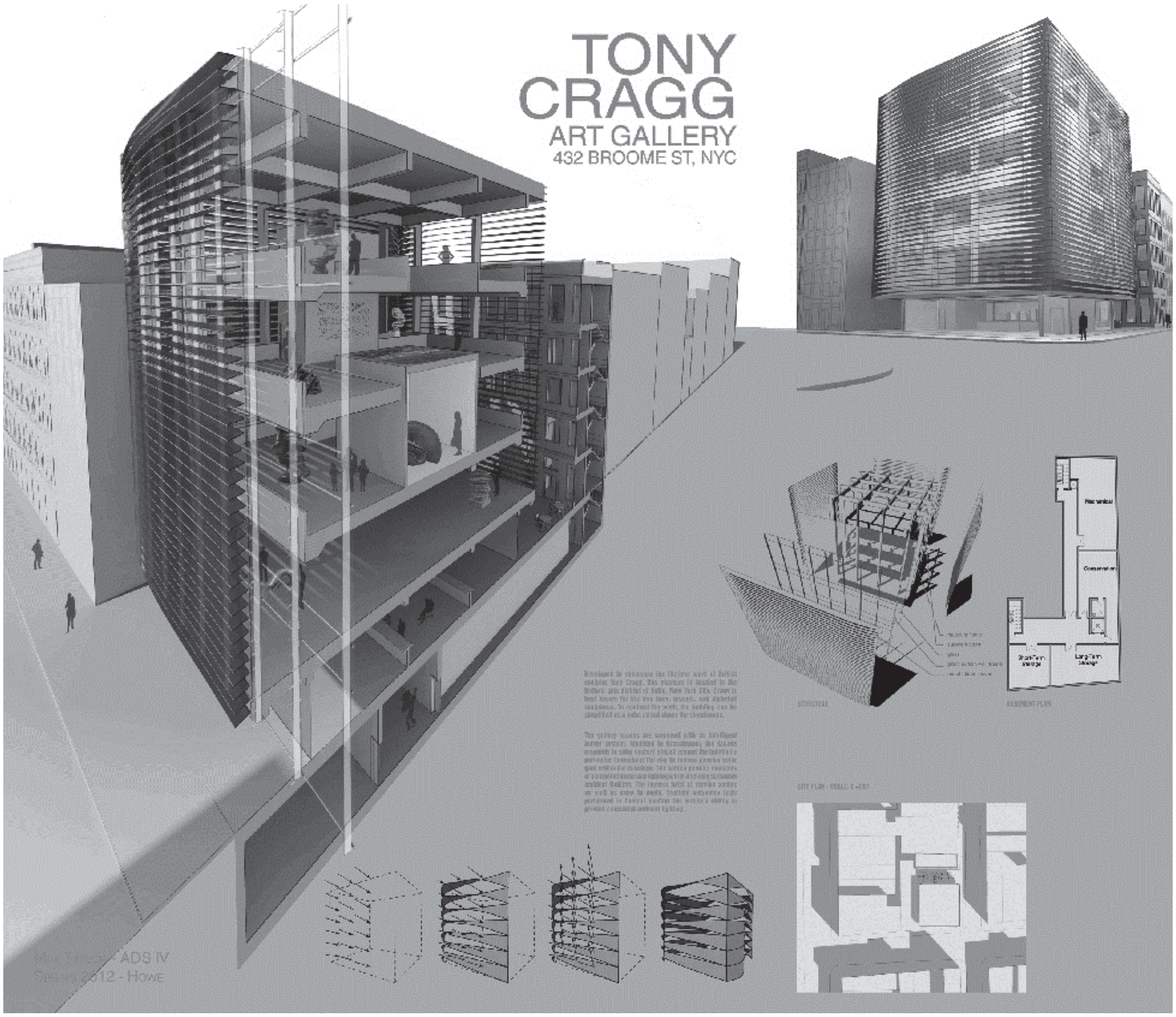

Figure 11: This image shows how one of the students used the experience from V.E.I.L.S. in a subsequent project later in the semester. Note the implementation of a choreographed sunlight study of a twisted louver system designed to block direct sunlight throughout the course of year in this sculptural museum.

REFERENCES

Figure References

Figure 1-10: Provided and executed by Howe's studio: Katie Bauer • Nadav Bittan • Jack Booton • Bryce Cummings • Jake Hofeling • Nick Kratz • John McLaughlin • Devin Murphy • JJ Nicolas • Christy Phelps • Chris Porreca • Caleb Riekhof • Max Taylor • Braden Thomas • Lindsey Telford

Figure 11: Provided by Max Taylor

References

[1] Ali Rahim, *Catalytic Formations: Architecture and Digital Design*, New York Taylor & Francis, 2006, 3.

[2] Hugh Whitehead*, "Instrumental Geometry," AD Techniques and Technologies in Morphogenetic Design,* Architectural Design, 2006, 45.

[3] Branko Kolarevic, "Computing the Performative" in, *Performative Architecture – Beyond Instrumentality,* edited Branko Kolarevic and Ali M. Malkawi, (Spoon Press, 2005), 195.

[4] Nathan Howe, “Augmenting Architecture through Algorithmic Modeling”, in *OZ Journal* volume 33, edited by Laura Beth Cochran and Samantha Smith, (Consolidated Printing, 2011), 48.

[5] The CNC mill is a Computer Numerically Controlled router mill used to cut woods, plastics and nonferrous metals.

[6] A. Kohn, *No Contest: The Case Against Competition*. Boston: Houghton Mifflin, 1986.

[7] Heinz Ronner & Sharad Jhaveri, *Louis I. Kahn: Complete work, 1935-1974,* Birkhauser Verlag, 1987, 354.

[8] www.solar.arch.vt.edu (accessed, January 31, 2013)

[9] Stephen Kieran, James Timberlake, *Refabricating Architecture,* McGraw-Hill, 2004, 6.

[10] Grasshopper is an explicit visual scripting plug-in for Rhino. This program allows for explicit geometric logic to be interconnected with external data to be imported for use within the script.

[11] Rhino or Rhinoceros is a nurb-based three-dimensional CAD modeling program.

[12] 3dsMAX is an Autodesk product which is primarily used for rendering and animating CAD models.

[13] SHoP/Sharples Holden Pasquarelli, *Versioning: Evolutionary Techniques in Architecture,* Wiley Academy, 2002, 7.

[14] Nathan Howe, “Parametric: Teaching Diagrammatic Design Processes”, (paper presented at the bi-annual conference of Design Communication Association, Oklahoma State University, Stillwater, Oklahoma, , October 21–24, 2012), 151.