

# Man + Water + Fan = Freshman

## Natural Process of Evaporative Cooling and the Digital Fabrication of the ASU Outdoor Dining Pavilion

Communication

Digital Fabrication

Environment

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TO THE EAST OF JOHNSON CITY TX IS THE LYNDON B. JOHNSON'S FAMILY HOME. Part of the Johnson Estate<sup>2</sup> is given over to a working farm circa 1870 that presents various aspects of domestic practice from the era. This includes a desert fridge which is a simple four-legged structure with a slightly battered profile that's draped in calico. Its principle is simple; water from an upturned jar is drawn by osmosis down the sides of the calico where it evaporates in wind currents drawn through a "dog run" between two log cabins. Cooled air circulates within the structure and where cheese and milk are kept fresh during the summer. The desert fridge is a simple system that reaches a state of equilibrium through the natural process of evaporation.

This system provides a working model for a prototype structure for an outdoor dining pavilion that was designed and constructed on the campus of Arizona State University. The desert fridge is the basis for a "biological process"<sup>3</sup> of evaporative cooling that has been interpreted in terms a ritual of outdoor dining in arid climates. The pavilion is intended as a gathering point and a place of interaction for ASU freshmen. The long-term aim of this project is to provide a multiple of these pavilions across the campus that will be the locus of a sequence of dining events over a "dining season"<sup>4</sup> during the fall and spring semester.

This paper describes how the desert fridge principle has been interpreted in the program and construction of the dining pavilion. It explores a sequence of levels by which the structure, via digital production process, provides an educational narrative on sustainability. This communicative quality is portrayed by the building in direct biological terms, through tacit knowledge, perceived phenomena, lexical and mechanical systems. The paper also describes how these digital production process were used in the building's design and fabrication. These range from an empirical prognosis of evaporative cooling effects, fluid dynamics, heat mapping and solar radiation analysis through to sheet steel laser cutting, folded plate construction and fully associative variable models of standard steel construction. The aim of the pavilion is to create an environment that presents the evaporative cooling message at a multiple of levels that will concentrate the visitor in holistic understanding of the processes imbued within the building.<sup>5</sup>

System



When you look at a building what do you see?

HENRI LEFEBVRE<sup>1</sup>

### 1 Jars and a table cloth.

For invited freshmen the experience of the pavilion begins prior to actually arriving. Each dining event is preceded by an invitation that is sent to the freshmen in a simple glass jar. The jar contains instructions printed onto a clear plastic sheet that describes not only the event but also what to do with the jar. The role of the jar is to establish an overture to the building through its iconography and association of its perceived functions. The jar comes in advance of the whole project and sets the tone for what is to follow.

Excerpt from an invitation:

*"INSTRUCTION:*

*THIS JAR IS AN INVITATION TO DINE AMONG FRESHMEN.  
PLEASE BRING IT ON (date) TO (campus location)."*

The simplicity of the jar is estranged by the nature of its role as an invitation.

*"INSTRUCTION:*

*WHEN YOU ARRIVE FILL THE JAR WITH WATER AND INVERT IT ONTO  
THE CLOTH STRIP WITH THE PLASTIC STRIP PROVIDED."*

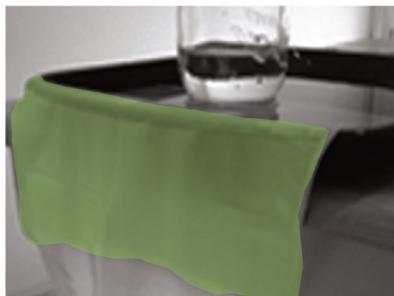
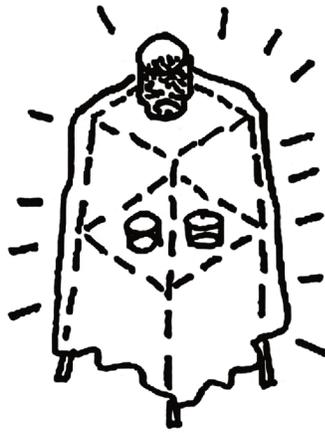
Using the jar in this manner is a deliberate appropriation of familiar dining rituals i.e. a glass vessel of liquid at each setting. However the jar is inverted. Water gradually seeps out of the jar and is drawn under osmotic pressure through the canvas. This canvas, like the inverted jar, shares affiliations with the dining ritual. Like the tablecloth in conveys a sense of a formal event. However, like the jar, the cloth is estranged from this familiarity i.e. it hangs inwards and invites the controlled accident of split liquid.

### 2 Fans—fluid dynamics

The jars and the cloth present two elements in the chain of events that make up the pavilion. At the center of the table is a 16" aluminum fan that hangs below the surface of the table which is driven by a roof mounted 50 watt direct current PV panel<sup>6</sup> (For the prototype structure the PV fan was hardwired to the DC motor although in the final proposed version solar generated electricity would be stored in batteries concealed below the floor structure) and drives air downwards onto a diverter and then horizontally through the inverted tablecloth. Air is cooled through the evaporative process and then blown onto the legs and midriff of the students dining at the table. The dinner continues and the students remain in the cooler environment as the water level in the jars gradually recedes in front of them. An empirical analysis of the system demonstrates a considerable drop off in ambient air temperature up to six feet from the tables center (Figure 4).

This can be demonstrated by a computational fluid dynamic model for an evaporative cooling system that is based on a 16" fan<sup>7</sup> generating airflow rates approx 2000 CFM operating at 1500 rpm. Air is blown equally in four directions below the table through an evaporative cooling membrane of heavy cotton (total area of 24 sq.ft) woven fabric with strands removed to provide greater percentage of perforation. Our working model studies<sup>8</sup> revealed that the most effective quality of perforation was around 30% of the fabric. These factor produced over a 20 degree difference between the table center and a distance of 6 feet in an ambient temperature of 98 degrees and during relative still air conditions. These temperatures were highly affected by wind currents around the pavilion being considerably cooler sitting in a down wind position.

FIGURE 1. DINING PAVILION



The scheme provides a cooled microclimate around the pavilion that is designed to sustain conversation, prolong the event and engender student interaction. However the empirical nature of this project is not, in itself, enough to directly communicate the message of the buildings system. This scheme is also arranged to communicate, via a sequence of physical components, several levels of comprehension of the buildings core concept. Each component of the building transcribes its particular role in the larger scheme in way that assist the visitor in a tacit and visual understanding of the buildings message and performance.

### 3 Visual and dynamic communication of internal systems.

Providing the visitor with the sight of a jar of water that gradually empties offers a direct visual and quantitative experience of the building's process. Henri Lefebvre writing in the *Production of Space* asks, "when you look at a building what do you see?"<sup>9</sup> In so doing refers to those acts, events and flows that occur within a building but are not considered architectural material per se. Lefebvre argues that such experiences are equal if not greater among architectural experience but commonly considered ancillary to conventional architectural discourse. A building may contain a swamp cooler although it is rarely considered as an architectural element. The change in state of a body of water passing through it is even less architectural. In this respect this pavilion attempts to expose similar aspects of the actual flows within the building and bring them to direct architectural contemplation. In exposing the physicality of the water along with its apparent change in state the building aims to engage and inform visitors about hidden environmental systems in a non-lexical way. Here the water becomes direct information and that information is conveyed as a physical fact directly and without recourse to codification, presented calculation or indeed any other assimilated mode of communication. In this respect it attempts to operate within a more universal context that belongs the category of global "Arid".

### 4 Fans—Function and association.

However the aim of this building is to communicate its concept over several of levels of environmental experience. Another such level demonstrates how the buildings language might dovetail with its function. If the recent history of sustainable design were to be considered in iconographic terms then the iconography of the fan might be central to this contemplation. While the role of the fan is crucial to the physical operating systems of sustainable design it is also a key element by which the ethic is promulgated within the widening debate on sustainability. At times the iconographic power of the fan exceeds its ability to perform effectively.<sup>10</sup>

This "both and"<sup>11</sup> interpretation of the fan has a particular take on the project and, in particular the design of the dining table. The functional necessity of the under-table air forces the tables fan out of sight and below the table and ensures that it plays a subversive role as a communicative architectural element. However the design of the table addresses this issue by developing its language through a projected pattern of enmeshed fans arranged to make up the table surface. This pattern is laser cut into 1/4" paintlock mild steel sheet that is then bent and formed into the table<sup>12</sup>. However this projection is also developed from a functional reading of this particular type of table and of outdoor furniture generally. In this case the level of perforation is designed to allow the passage of cool air through the table and onto the diners. The perforation also borrows from the functional typology of outdoor furniture that is perforated to allow rainwater to pass through it and also to reduce its thermal mass in hot temperatures. In this way the fan acts as a visual communicator and simultaneously a functional element.

### 5 Structure

However the size of the table means that it can only effectively communicate its performance within close visual proximity. It is too small to propagate its message to the wider context of the campus.

This scale of communication is then transferred to the shade structure that sits above

FIGURE 2. DESERT FRIDGE AND EVAPORATIVE COOLING MODEL.

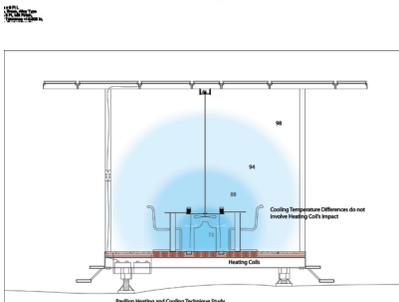
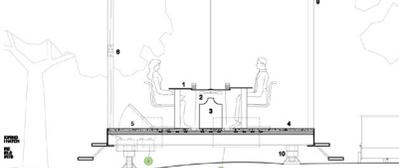
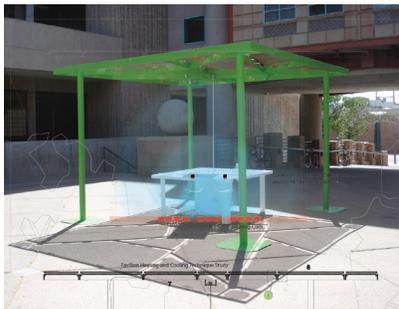


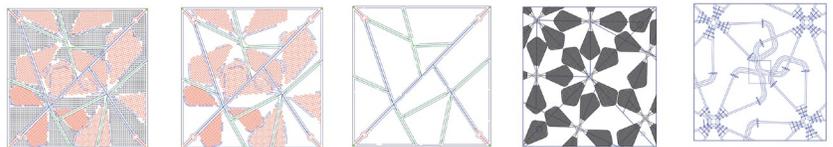
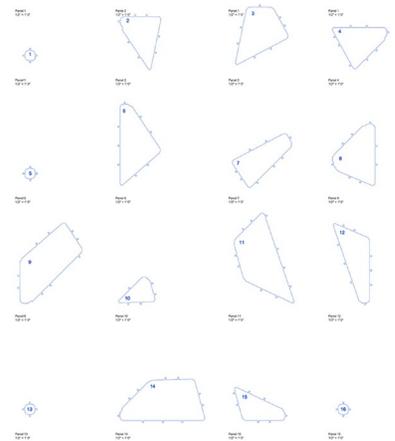
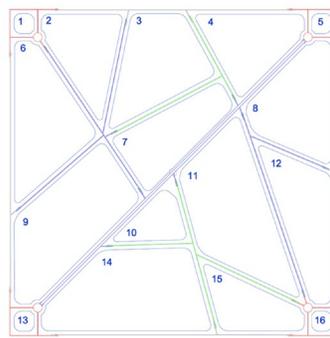
FIGURE 3. (TOP LEFT) DETAILED SECTION

FIGURE 4. TEMPERATURE DROP OFF AROUND TABLE (THE HEATING COILS BELOW THE SURFACE WERE DESIGNED TO WARM DINERS THROUGH CONTACT DURING THE COOLER EVENINGS)

FIGURE 5. LASER FAN PATTERN FUNCTIONS TO ALLOW PASSAGE OF COOLED AIR THROUGH THE STEEL TABLE AND TO REDUCE THERMAL MASS.

FIGURE 6. ROOF STRUCTURE AND PERFORATED PANEL PATTERN FROM STANDARD STEEL SECTION

FIGURE 7. (TOP RIGHT) ROOF STRUCTURE AND PERFORATED PANEL PATTERN GENERATED FROM ASSIMILATION OF FAN IMAGE AND VERONI DIAGRAM OF FAN AXES.



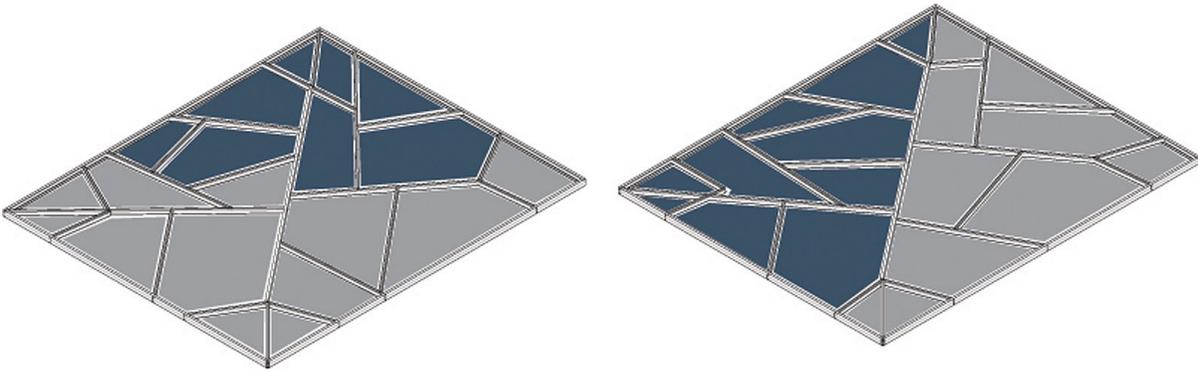
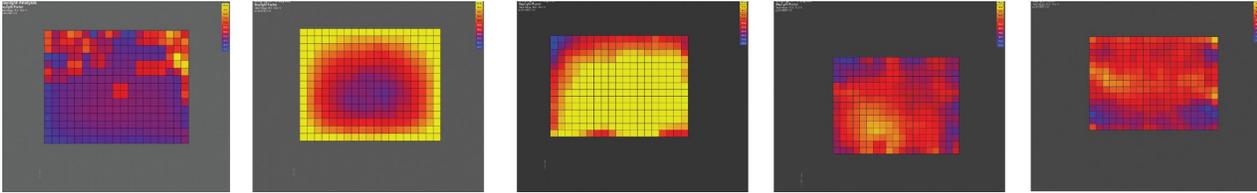
the table. Here again the iconography of the fan is assimilated into the building as a mesh of primary and secondary structural roof beams along with perforated infill patterns. In this case the fan iconography was developed by generating a Veroni diagram of the regulating lines of individual fan axes. The underbelly of the structure (lit at night) presents a prospect of this assimilated pattern language seen from afar and from various angles around the campus. Again these iconographic elements are inextricably bound to the structure's functional responsibilities and place in the chain of activities that can be traced back to the physical (and conceptual core) of the jar of water. In this case the structure is designed to support sequence of PV shade panels. These panels are set above the shade perforated shade panels and comprise of polycrystalline PV elements laminated between sheets of toughened glass (again this is "as proposed". The actual prototype incorporates a conventional framed PV panel). Each panel is designed to directly charge the batteries that are stored below the suspended floor.

## 6 Parametrics and site position.

The arrangement of these patterns are specific to the location and orientation of each individual pavilion.

Each pavilion site is chosen for its proximity to existing shade on the campus and its exposure to direct sun. Each pavilion requires a combination of both i.e. a certain amount of direct sun to charge the batteries and an amount of shade for afternoon comfort during low sun angles. Each site is derived from a set of solar radiation studies<sup>13</sup> taken from a range locations from across the campus. These studies were then interpreted in terms of the configuration and position of the PV units within the roof structure i.e. enough area to provide adequate solar exposure to charge the batteries.

Each structure responds to these different configurations of light and shade pattern in that they are designed as permutations of a basic parametric model. Each model is comprised of a network of standard steel sections that are joined with associative connections. In this way each unique pattern of light can be accommodated with minimal alterations to the basic underlying sketch of structural lines within the program<sup>14</sup>. Modifying the sketch allows a speedy alteration of the whole model and each model is directly translated into cutting patterns that that can be quickly generated as production information for steelwork fabricators<sup>15</sup>. Together these aspects of the roof structure aim at another interpretation of



the buildings role. Here the core theme of the building finds another visual and functional element arranged to communicate the buildings stance on sustainability.

### 7 Conclusion.

In this project function, message, performance and iconography are inextricably linked in theme of communication and education of sustainable design.

The ASU outdoor dining pavilion present a prototype for a building that is designed to engender social discourse among freshman students on entering the university. This paper suggest that the theme sustainability is herein portrayed architecturally through multivalent readings of facets of a core concept of evaporative cooling.

While the workings of environmental aspects of architecture are, in many ways, invisible at times architecture conventionally relies upon the mechanical aspect of environmental systems to portray such allegiances. In most cases however these mechanical systems are not considered to be architectural. This project suggest that such conventionally internalized themes can be explored through both tradition and non-traditional architectural modes of communication. The core concept of this project is strategically set at the buildings center of focus. Here the natural process of cooling is played out as part of both a leisurely and informative ritual for diners. In this way the building is to be seen as educational in a direct physical way. From this conceptual core of natural evaporation emanates several “transferences” that are portrayed through the buildings composition, fabrication, structure and environmental effect. This paper describes these processes and how such aims can be achieved through digital design. It suggest that a digitally assisted approach to sustainable design can offer a wider set of considerations that include, but are not exclusive to, a functional interpretation of sustainable goals.

### 8 Endnotes

1. *The Production of Space*—Henri Lefebvre Wiley-Blackwell (April 15, 1992).
2. Lyndon B. Johnson State Park and Historic Site. Hwy. 290 E. at Park Road 52, Stonewall, TX 78671
3. <http://www.acadia.org/acadia2008/>—Call for papers text.
4. “A Pavilion will be a unique but elemental and simple structure. Approximately 12’ x 16.’ (thus very small), each Pavilion will feature an architecture that is designed to accommodate intimate student gatherings in a

**FIGURE 8.** ECOTECT SOLAR RADIATION DIAGRAMS FOR DIFFERENT CAMPUS LOCATIONS TO ASSESS OPTIMAL PV PANEL ARRANGEMENTS.

**FIGURE 9.** TWO VARIATIONS OF THE PARAMETRIC SOLIDWORKS MODEL USING ASSOCIATIVE STEEL SECTION MODELING MODIFIERS

- very purposeful manner. The designs will be demonstrations of sustainability, community, inventiveness, and will add a vital physical contribution to the campus. But as the vessels in which the most engaging conversations on campus are sponsored, they will represent something even larger” Brief from the Outdoor Dining Pavilion, Dean of School of Architecture and Landscape Architecture, ASU in collaboration with Bruce Mau.
5. All detailed design and fabrication work carried out in collaboration with students from ASU Department of Architecture and Landscape Architecture, Integral studio , Spring 2008
  6. DC Motor: Permanent Magnet, Totally Enclosed Non-Ventilated, HP 1/35, RPM 2350, Voltage 12 DC, Full Load Amps 3.8,
  7. Aluminum Fan Blade: Diameter 16 Inches, Motor Power Rating 1/40HP, 1050 RPM
  8. Initial working model was based on a simple soaked cloth and re-arranged house fan.
  9. *The Production of Space*—Henri Lefebvre Wiley-Blackwell (April 15, 1992).
  10. For example the RIBA center in Portland Place, London proposed a wind turbine on the roof. “RIBA’s wind turbine hopes blown out by council planners. The RIBA’s plans to provide a model for sustainable architecture have been foiled by Westminster City Council, which is set to refuse planning permission for two wind turbines on the roof of its headquarters building in Portland Place. Planning officers are recommending that the Allies and Morrison scheme to add the 20m turbines to the top of the building should not go ahead. Officer Robert Ayton said the objections were ‘on the basis of visual impact’. [http://images.google.com/imgres?imgurl=http://www.greenconstruction.co.uk/images/Bookshops\\_03.gif&imgrefurl=http://www.greenconstruction.co.uk/archive/roundup034.asp&h=150&w=150&sz=9&hl=en&start=1&um=1&tbnid=GACii\\_9Y2tWeBM:&tbnh=96&tbnw=96&prev=/images%3Fq%3D%2522RIBA%2Bwind%2Bturbine%2522%26um%3D1%26hl%3Den%26client%3Dsafari%26rls%3Den%26sa%3DG](http://images.google.com/imgres?imgurl=http://www.greenconstruction.co.uk/images/Bookshops_03.gif&imgrefurl=http://www.greenconstruction.co.uk/archive/roundup034.asp&h=150&w=150&sz=9&hl=en&start=1&um=1&tbnid=GACii_9Y2tWeBM:&tbnh=96&tbnw=96&prev=/images%3Fq%3D%2522RIBA%2Bwind%2Bturbine%2522%26um%3D1%26hl%3Den%26client%3Dsafari%26rls%3Den%26sa%3DG)
  11. *Learning from Las Vegas* P.72—Venturi Scott Brown Izenour—The MIT Press
  12. For 20 gauge the laser ran at 2900 mm/minute at 3600 Watts while for the 1/4” ran at the same feed rate but at 3600 Watts.
  13. <http://squ1.com/products/ecotect>
  14. For more information on this see <http://www.solidworks.com/pages/onlinetour/popup.cfm>
  15. All fabrication carried out by K- Zell Metals, Inc 1725 East Broadway Road, Phoenix, AZ 85040-2407 and Fine Line Fabrication 17464 N 25th Ave, Phoenix, AZ 85023