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The Crucible of Construction: Designing and Building the UNLV Solar Decathlon House

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The Crucible of Construction: Designing and Building the UNLV Solar Decathlon House

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Abstract

In Fall 2011, the University of Nevada – Las Vegas School of Architecture's David G. Howryla Design – Build Studio began development of UNLV's entry into the U.S. Department of Energy Solar Decathlon 2013, an international, university-based competition to design solar-powered housing prototypes. The design team's primary goal was not the creation of a workable engineering model; instead, the team explored how technology can be a tool that assists people to reconnect with materiality, texture, light, and time, creating opportunities for memorable experiences.

As the only university located in the Mojave Desert, one of the most extreme environments in North America, UNLV was offered a unique opportunity to demonstrate leadership in developing innovative responses to arid climates, and finishing in 2nd-place overall underscored our team's abilities. As many parts of the world are experiencing significant climate change-related water shortages, our responses to these issues can have impacts beyond the Las Vegas region.

The harsh environment, exceptional dryness, and intense contrast of sunlight and deep shadows have a profound impact on how we perceive and inhabit the desert. Team Las Vegas made material selections that reflect these challenges by choosing natural, durable materials that age well in the desert, while allowing the passage of time to be recorded in their surfaces, recording the processes of change as positive contributors to the building's character.

Knowledge is not acquired through passive transmittance and receiving of information; one gains true understanding through active formulation. It is through active participation in the creation of knowledge that it truly becomes one's own. The crucible of construction uncovers difficulty, reveals deficiencies in designers' understanding, and underscores the need for effective communication of design intent. These lessons will be invaluable for both the participating students, and for the faculty as the Design Build Studio begins work on future projects.

Keywords: design-build, materiality, tectonics

The Crucible of Construction: Designing and Building the UNLV Solar Decathlon House

In Fall 2011, the University of Nevada – Las Vegas School of Architecture's David G. Howryla Design – Build Studio began development of UNLV's entry into the U.S. Department of Energy Solar Decathlon 2013, an international, university-based competition to design solar-powered housing prototypes. The design team's primary goal was not the creation of a workable engineering model; instead, the team explored how technology can be a tool that assists people to reconnect with materiality, texture, light, and time, creating opportunities for memorable experiences.

Design build education is an ideal pedagogy for developing a designer's skills. Teamwork, workmanship, and understanding are necessary to form the synthesis needed to create compelling projects. Technique is derived from the Greek techne, which means 'the rational method involved in producing an object, goal, or objective;' Aristotle describes craft as itself also *epistêmê* or knowledge as a practice grounded in an 'account' – something involving theoretical understanding. (Parry, 2008) This blending of workmanship and understanding is critical to a student's development of a coherent design process. Students must learn to develop a working method that advances their ability to synthesize complex pieces of data into a coherent whole.

Carlo Scarpa's design method has been characterized as a virtually unbroken line from the act of drawing to the act of making. Marco Frascari characterized his method as a reciprocity between construing form and constructing it. Scarpa himself acknowledged this relationship when he was made dean of the Venice University Institute of Architecture; he inscribed the legend "Verum Ipsum Factum" on the diplomas, and later the portal above the school's entry. This dictum, "truth through making," has strong antecedents in the writings of Giambattista Vico, who believed that knowledge was not acquired through passive transmittance and receiving of knowledge; one gains true knowledge and understanding through active formulation. In other words, by doing. It is through active participation in the creation of knowledge that it truly becomes one's own. (Frampton, 1995, p. 307-8)

Architects and engineers do not work in abstractions; they need to understand the solidity of matter, the resistance, weight, strength, and weakness of real materials. In a design-build project, Scarpa's dictum is put to the test. The crucible of construction uncovers difficulty, reveals deficiencies in designers' understanding, and underscores the need for effective communication of design intent. These lessons have been invaluable for both the participating students and faculty as the Design Build Studio competed in the Solar Decathlon, as well as during the transition to new projects.

The Art and Craft of Building

A vital component to any architect's education is learning how to effectively utilize building materials as carriers of architectural meaning; the development of a coherent tectonic language is fundamental to teaching spatial design and architecture. A conventional design education provides limited time to learn and practice the many skills associated with craft, including but not limited to model building, digital modeling, fabrication, full-scale construction, and detail development. Educators must responsibly lay the groundwork for processes and methods that foster innovation and introduces highly complex tools to creative students through design-build projects. This foundation is built on the understanding that craft supplements innovation by teaching designers to act with care and intention, developing curiosity, discovering applications, and developing skills and understanding of materials, tools, and methods.

The key to our design process is challenging students to prototype in order to ideate, rather than the other way around. This requires students to play with ideas, methods, materials, and techniques as a way to find, test, and investigate solutions that are not always obvious. It also requires students to understand that these processes provide valuable learning opportunities. Craft is the engine that drives students to pose innovative propositions in their design process and results.

UNLV Design-Build Studio's Approach to the Solar Decathlon

When we began work on DesertSol, Team Las Vegas' Solar Decathlon entry, we determined that our operative principle was that isn't a solar project first; it is a *house* first. This was a critical determination, as it strongly informed all following decisions. While it was essential to the success of the project that all of the engineering systems be innovative, the engineering systems should support this mission, rather than the other way round. We determined that it was imperative that Team Las Vegas design a credible, serious project that celebrated the uniqueness of our location, climate, and culture, without resorting to clichés or predictable, 'safe' responses. The following passage from Juhani Pallasmaa's The Eyes of the Skin had a particularly profound impact on the design team:

> In recent decades, a new architectural imagery has emerged, which employs reflection, gradations of transparency, overlay and juxtaposition to create a sense of spatial thickness, as well as subtle and changing sensations of movement and light. This new sensibility promises an architecture that can turn the relative immateriality and weightlessness of recent technological construction into a positive experience of space, place and meaning. (Pallasmaa, 2005, p. 32)

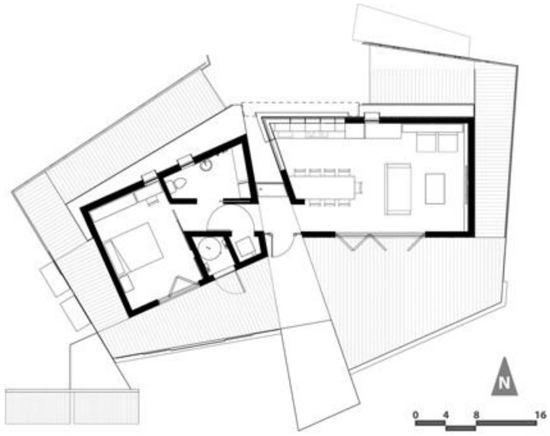
Good architecture creates a sense of place and inspires memorable experiences. Thoughtful consideration of comfort, scale, light, and sensory experience distinguish a home from a simple shelter – these are the qualities people look for in a well-designed custom home. Phenomenological considerations like these are as relevant now as ever – perhaps more so, with society's preoccupation with the virtual environment; people need a release from the stresses of contemporary life. Our aim with DesertSol was to offer such an experience – an experience that is of the desert, while incorporating high-tech features into everyday living.

The Springs of Las Vegas

One of the critical components of the Design-Build Studio's process was to explore the history of Las Vegas and Southern Nevada. Creating a positive experience of space, place and meaning, as Pallasmaa writes, necessitates a careful reading of the particular qualities that have brought a place into being. Our community began as an oasis, due to the existence of the Las Vegas Springs, the only significant water source within a day's ride by horse from the Colorado River. The first Spanish settlers called this place "Las Vegas," or "The Meadows", after the grassy fields fed by this vital resource. The springs, located in the heart of today's Las Vegas Valley, were the reason why Native Americans, the Mormon pioneers, and the railroad depot all decided to settle in this desert. This resource disappeared in merely fifty years due to the falling water table, caused by overdrawing from the aquifer. Las Vegas is now overdrawing its water reserve in Lake Mead, and is in danger of repeating this history. It is one of Team Las Vegas' primary goals to demonstrate water conservation strategies and to underscore how essential these techniques are to the survival of our community.

In recognition of the importance of this vital resource to our community identity, DesertSol is organized as two modules, separated by a narrow entry space. The entry looks northward through the space between the modules, framing the sky above, and a shallow pool of water below. The house becomes an analog for the stones between which water bubbles to the surface, forming a desert spring. This pool is designed to be a catch basin for occasional desert downpours, collecting the precious four inches of precipitation each year and storing it in a cistern. The storm runoff from both roofs travels via gutters to the roof of the foyer and pours into the pond like a waterfall. (Fig. 1, 2) The water then trickles over the edge of the pool, and is captured in a small trough at the entry court; its form is a reference to watering troughs for thirsty horses, while also creating the essential sound that provides psychological comfort in our dry land. In addition, this fountain creates evaporative cooling and passes cooled, re-humidified air through a low window in the kitchen into the living spaces. The rainwater is also used in landscape irrigation, although little water is required to supply the native plants the team incorporated into the design. In time, as they establish roots into the surrounding soil, the desert foliage will thrive solely on the water provided by this resource.

Figure 1. *DesertSol Floor Plan*



Source(s): Eric Weber/UNLV Design Build 2013

Figure 2. *Rainwater Catchment During SD 2013*

Source(s): Alexia Hsin Chen/UNLV Design Build 2013

A Study in Materials

The harsh environment, exceptional dryness, intense contrast of sunlight and deep shadows have a profound impact on how the desert is perceived and inhabited. The passage of time has different effects on materials relative to other places, and recognizing these differences is essential to responding to this environment on its terms. The desert is particularly unforgiving to synthetic materials and coatings. Team Las Vegas made material selections that reflect these challenges by choosing natural, durable materials that age well in the desert, while allowing the passage of time to be recorded in their surfaces through the action of the environment and the building's use. The building's materials record these processes as positive contributors to its character.

DesertSol's material palette is marked by the contrast of aged, rugged exterior and polished, finely detailed interior finishes. The primary components are wood and steel – some of the first mass-produced building materials originally available in Nevada. Metal roofing came west with the railroads, and with the advent of sawmills in the Mount Charleston area and elsewhere across the state harvesting Ponderosa Pine, sawn lumber became a ubiquitous building material by the early 20th century in Las Vegas. Many of the silver mining towns built with these materials later became the ghost towns of western lore; their weathered silver-gray wood and rusted/weathered steel inspired the exterior appearance of DesertSol.

The intensity of the sun requires a careful analysis and equally thoughtful response. Trapping the heat generated by this abundant energy source is a major challenge, one that the architecture should respond to on its terms. Materials that cool rapidly, and compositions that avoid trapping solar radiation, are essential to effectively responding to the sun. By creating perforated metal shades, overhangs (created from both perforated and solar panels) that allow free passage of heat through gaps in the covering, roof surfaces that rapidly shed their heat, a reclaimed "shadescreen" wall system, and other strategies, one can respond to the pragmatic need for comfort and the urban heat island, as well as the poetic possibilities of life under a comforting shade canopy – a reference to our ancient tree-dwelling forebears, deeply rooted in our collective unconscious.

The interior features wood reclaimed from shipping crates that has been repurposed into polished, tongue-and-groove flooring. Steel fabrications appear inside the house, but will not rust like the exterior steel; they will age as the house is occupied and will be polished by human touch.

Figures 3-4. *DesertSol Exterior*

Source: Kevin Duffy 2013

Figures 5-6. *DesertSol Interior*

Source: Kevin Duffy 2013

Virtual vs. Reality

One of the unintended side effects of the embracing of the virtual has been the tendency among many students towards a lack of rigor in considering the actual materials from which their buildings are to be constructed. Design-build projects serve as an effective counterpoint to this challenge; in addition, they offer the opportunity for deeper thinking.

> The modern machine's threat to developing skill has a different character. An example of this misuse occurs in CAD… In architectural work, however, this necessary technology also poses dangers of misuse… (Sennett, p. 39)
>
> How could such a useful tool possibly be abused? When CAD first entered architectural teaching, replacing manual drawing by hand, a young architect at MIT observed that 'when you draw a site, when you put in the counter lines and the trees, it becomes ingrained in your mind. You come to know the site in a way that is not possible with the computer… You get to know a terrain by tracing and retracing it, not by letting the computer 'regenerate' it for you.' This is not nostalgia: her observation addresses what gets lost mentally when screen work replaces physical drawing. As in other visual practices, architectural sketches are often pictures of possibility; in the process of crystallizing and refining them by hand, the designer proceeds just as a tennis player or musician does, gets deeply involved in it, matures thinking about it. The site, as this architect observes, 'becomes ingrained in the mind.'
>
> The architect Renzo Piano explains his own working procedure thus: 'You start by sketching, then you do a drawing, then you make a model, and then you go to reality – you go to the site – and then you go back to drawing. You build up a kind of circularity between drawing and making and back again.' About repetition and practice

> Piano observes, 'this is very typical of the craftsman's approach. You think and you do at the same time. You draw and you make. Drawing… is revisited. You do it, you redo it, and you redo it again.' This attaching, circular metamorphosis can be aborted by CAD. Once points are plotted on-screen, the algorithms do the drawing; misuse occurs if the process is a closed system, a static means-end – the 'circularity' of which Piano speaks disappears." (Sennett, p. 40)

> Computer-assisted design poses particular dangers for thinking about buildings. Because of the machine's capacities for instant erasure and reconfiguring, the architect Elliot Felix observes, "each action is less consequent than it would be on paper… each will be less carefully considered." (Sennett, p. 41)

Paradoxically, it has been my observation that while this is true, another, unexpected problem has become commonplace; student resistance to change, once something is "in the computer." For some reason, despite the fact that has been input to the computer becomes nothing more than pixels and algorithms, many students vigorously resist the iterative process, once they have created a scheme into the computer. I believe this is due to the fact that the computer demands determinacy; if you want to draw a box, the computer prompts the user for the size of the box, as well as its position in the X, Y, and Z axes. This precision, while extremely useful when the designer knows exactly what is required (as when creating construction documents, for example) is a major impediment to continual refinement.

Some architecture faculty have in the past recognized this challenge, and have responded by restricting students from using CAD software early in the design process; but this understandable reaction is also problematic. In my professional experience, we used CAD software in the formative stages, but not to construct design concept models; we used the software to create volumes based on the relative size of each element in the building program, with their areas determined precisely based on this document. We would then use these volumes to study adjacencies and organizational strategies, among other design determinants. The multiple variations on these possible strategies would be printed, and a process of sketching and overlaying would commence; sometimes we cut out the volumes and rearranging them manually, and completed multiple overlays, which would then be fed back into the computer. By taking advantage of the computer's need for determinacy, this strategy allowed us to efficiently develop multiple iterations, reconnecting with the reciprocity Renzo Piano discusses in this text.

> Returning to physical drawing can overcome this danger; harder to counter is an issue about the materials of which the building is made. Flat computer screens cannot render well the textures of different materials or assist in choosing their colors, though the CAD

> programs can calculate to a marvel the precise amount of brick or steel a building might require. Drawing in bricks by hand, tedious though the process is, prompts the designer to think about their materiality, to engage their solidity as against the blank, unmarked space on paper of a window. Computer-assisted design also impedes the designer in thinking about scale, as opposed to sheer size. Scale involves judgments of proportion; the sense of proportion on-screen appears to the designer as the relation of clusters of pixels. The object on-screen can indeed be manipulated so that it is presented, for instance, from the vantage point of someone on the ground, but in this regard CAD is frequently misused; what appears on-screen is impossibly coherent, framed in a unified way that physical sight never is. (Sennett, p. 41)

Scale is a constant challenge for computer-driven design; because the actual interface is two-dimensional, it is challenging for students to perceive the effect of the relationship of their designs to the human body. This is precisely why physical models were the sole deliverables during the development of the Solar Decathlon conceptual design. Students were free to use any methodology they wished in order to arrive at their schemes, but each week, they were required to construct physical models. This was a direct challenge to students' tendency to do the majority of their work using their computers. There were several reasons for this strategy. Each mode of representation (drawing, CAD, physical model, etc.) requires students to analyze and evaluate their designs in a different manner, revealing new possibilities.

Additionally, by enforcing the necessity for at least one additional methodology, the iterative process became a requirement embedded in their work, and thus inscribed in their evaluations. In addition, by requiring multiple physical models each week, students found it necessary to discard their tendency toward the pristine, precious model, done as a validation of their work, and consequently, they discovered that model-building helped them to better understand their designs. During critiques, when I routinely removed components, collaged models together, and made other alterations to demonstrate key refinements, students slowly embraced this process, resulting in much richer, thoughtful finalist designs.

This digression into our design process is not particularly groundbreaking, but it leads to a critical point; making actual things, rather than representations of things, is essential to an architect's development, particularly in the digital age. Architects must understand the physical, real materials from which their buildings are constructed, and the perceptual qualities each of them embody.

I reject the idea of an opposition between digital and physical; in fact, in the hands of visionary architects such as SHoP, Kieran Timberlake, and others, the critical use of digital tools offers the promise of the architectural profession to regain the role of "master builder." In order to fabricate digitally, designers must really understand the physical reality of the materials you to be utilized in the design. Our students discovered the importance of the iterative process as they attempted to turn their screen images into constructed reality.

> Drawing in bricks by hand, tedious though the process is, prompts the designer to think about their materiality, to engage their solidity as against the blank, unmarked space on paper of a window. (Sennett, p. 41)

This statement by Sennett about how tediousness can offer the possibility of real thinking, is reminiscent of a statement by the artist Hiromichi Iwashita, in which he talks about the act of carving as "boring." The artist starts out without a specific idea in mind, and only through the repetitive process of carving does the image reveal itself.

> Carving wood, or its repetitious process, is a boring act, especially in its early stage when no particular image is present. As such, my initial concern is the size of a panel, its format and thickness. I face the panel directly with little idea, with no sketches or models to form thoughts and future plans of the end result. Existing limitations of the particular panel may even motivate creativity. In fact, this might at the same time prove unconsciously to be one of the aims of my work.
>
> Eventually, as daylight lessens, small markings left by my carving knife with their accumulation of gentle sounds produces a graduation of shades. It is not the beginning of a story but rather like fetal heartbeats or movement. Carving turns into listening to such sounds. It is not a conscious shaping, but a yielding to what might be suddenly taking shape and being encouraged by the sign of an object emerging as a field.
>
> When my work reaches the final monotonous stage of covering those carved marks with graphite and polishing them, I must wait for the light. However, if that light is the harsh, direct sunlight of midday, the whole process might be wasted by exposing a rough and naked object. What is desirable are the gentle, interactive rays of light.
>
> What I am constantly thinking of is not art work as such but the field of lights and sounds that emerge from this process of interaction between an object and my body. (Iwashita, 2000)

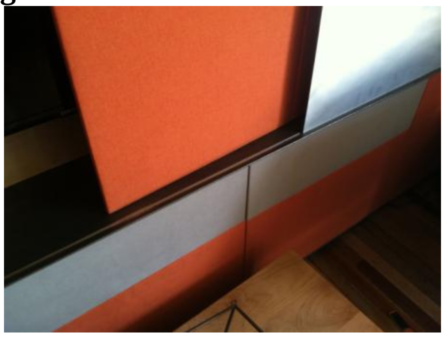
This process of practicing something repeatedly, until one is no longer specifically thinking about it, seems essential to the development of the craftsman ethos. This way of working/thinking is not valued in contemporary educational pedagogy, for fear of losing students' interest. By taking these kinds of experiences away from students' education, we are shortchanging their development.

> The tactile, the relational, and the incomplete are physical experiences that occur in the act of drawing… The difficult and the incomplete should be positive events in our understanding; they should stimulate us as simulation and facile manipulation of complete objects cannot. The issue – I want to stress – is more complicated than hand *versus* machine. Modern computer programs can indeed learn from their experience in an expanding fashion, because algorithms are rewritten through data feedback. The problem, as Victor Weisskopf says, is that people may let the machines do this learning, the person serving as a passive witness to and consumer of expanding competence, not participating in it… Abuses of CAD illustrate how, when the head and the hand are separate, it is the head that suffers.
>
> Computer-assisted design might serve as an emblem of a large challenge faced by modern society: how to think like craftsmen in making good use of technology. "Embodied knowledge" is a currently fashionable phrase in the social sciences, but "thinking like a craftsman" is more than a state of mind; it has a sharp social edge. (Sennett, p. 44)
>
> Skill is a trained practice; modern technology is abused when it deprives its users precisely of that repetitive, concrete, hands-on training. When the head and the hand are separated, the result is mental impairment – an outcome particularly evident when a technology like CAD is used to efface the learning that occurs through drawing by hand. (Sennett, p. 52)

Perhaps one of the most convincing demonstrations of the need for designers to engage in the physical act of building, and the perceptual experiences that thoughtful design work can make possible was the process of developing the acoustic wall assembly housing the entertainment system. (Fig. 7-8) Graduate students Lee Consterdine, Kristen Madden, and David McCredo conducted extensive material, hardware, and equipment research in order to complete this essential component of the house, as the home entertainment contest wass critical to the competition, and acoustic performance is essential to creating the perceptual qualities many prospective buyers desire in a home. The Market Appeal jury agreed with this decision, awarding UNLV first place in this competition, specifically identifying the sound quality and the system's performance. The acoustical absorption eliminated the echoes and "live noise" that may have been caused by having too many hard surfaces.

An interesting point about this component is that many of the students working on the project openly questioned the necessity of having an acoustic absorber in the house. Several of the student team leaders were surprised by the effect this assembly had on improving the character of the house, virtually transforming the character of the building. This example illustrates the necessity of experiencing real spaces, rather than reading about them. It is through direct experiences that one begins to understand the implications of design decisions.

Figures 7-8. *DesertSol Acoustic Wall Detail, Interior*



Source(s): Eric Weber/UNLV Staff Photographer

> 'Heidegger famously noted that the way we come to know a hammer is not by staring at it, but by grabbing hold of it and using it.' For him, this was a deep point about our apprehension of the world in general. The preoccupation with knowing things 'as they are in themselves' he found to be wrongheaded, tied to a dichotomy between subject and object that isn't true in our experience. The way things actually 'show up' for us is not as mere objects without context, but as equipment for action (like the hammer) or solicitations to action… within some worldly situation. One of the central questions of cognitive science, rooted in the prevailing epistemology, has been to figure out how the mind 'represents' the world, since mind and world are conceived to be entirely distinct. For Heidegger, there is no problem of *re*-presenting the world, because the world *presents* itself originally as something we are already *in* and *of*. His insights into the situated character of our everyday cognition shed light on the kind of expert knowledge that is also inherently situated, like the firefighter's or the mechanic's. (Crawford, p.164)

Design-build projects have the possibility of reinvigorating this learning opportunity, particularly where students are actually doing much of the finish work. With longer-term projects like a Solar Decathlon house, most of the students who worked on the design only had a limited exposure to this idea, as most of the finishes were applied during the summer, and due to the low number of students working on it during this period, it was be necessary to have much of this work done by professionals. Those involved benefitted greatly, but the impact was more limited than intended. This is an essential reason to complete design-build projects during the regular academic schedule whenever possible. It also suggests that using SIPS or other quick-assembly methods would allow more time for finish work during the semester.

As stated earlier, the crucible of construction uncovers difficulty, reveals deficiencies in designers' understanding, and underscores the need for effective communication of design intent. Hands-on building emphasizes difficulty; your success or failure is there for everyone to see; it cannot be explained away. A windowsill is either level, or it isn't, for example. The resort to objective standards is an essential lesson for architects to internalize. What does it mean that we're training a generation that can recite facts, but can't "do anything?" The arguments made by Crawford and Sennett are particularly compelling, and are central to my teaching methods. When you build something, you use very different parts of your brain and your body to accomplish the task. The fusion of hand and mind is essential to becoming a thoughtful designer, and will continue to guide the work of the Design Build Studio.

Figure 9. *Perforated Screen at Night*

Source: Kevin Duffy 2013

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