The Collaboration for the Solar Decathlon

An Honors Thesis (ARCH 402)

By

Jeff Thornberry

Thesis Advisor
Michele Chiuini

Ball State University
Muncie, Indiana

April 2012

Expected Date of Graduation
May 2012
Abstract

The Solar Decathlon is a biennial, award-winning program in which collegiate teams compete to design, build, and operate the best solar-powered house based on cost, energy, and attractiveness. The main purpose of the competition is to teach students about clean energy and provide them with unique training that will help them in their future careers ("About Solar Decathlon").

Ball State University, University of Louisville, and University of Kentucky, as a team, submitted a proposal to the U.S. Department of Energy and were accepted in the spring of 2012 to compete in the Solar Decathlon 2013. BSU is responsible for the architectural design while UofL and UK are responsible for the engineering design.

The spring semester of 2012 was devoted to designing a well-researched schematic design for the house that will be further developed in the later phases of the design process. In this thesis, I will discuss the unique experience of working with multiple disciplines on an architecture project as a participating architecture student.

Acknowledgements

- First of all, I want to thank my studio professor and thesis advisor, Michele Chiuini, for all of his input and guidance during this unique and, at times, challenging semester.

- I want to thank my partner during the first phases of the project, Daniel Potash, for the time and effort he contributed to this project. It was a pleasure to work with him.

- I want to thank everyone at Ball State University who has been involved with the Solar Decathlon.

- Finally, I want to thank everyone at the University of Louisville and the University of Kentucky who has been involved with the design process.
Organization

The Solar Decathlon (SD) consists of ten contests in which the house will be assessed: architecture, market appeal, engineering, communications, affordability, comfort zone, hot water, appliances, home entertainment, and energy balance. Obviously, many of these contests are not directly influenced by the architecture of the home. The contests that we, the architecture team, were most concerned with during the first phases of the project were architecture and market appeal. While they still require input and influence from the engineering team, they are not directly controlled by them. However, some aspects of the engineering, such as energy and placement of the solar panels, had a large influence on architectural decisions.

The first work done on the SD house took place during the 2011 fall semester. Professor Chiuini taught a third year studio, with each student designing a solar house that would be a suitable start for the SD submission. The collaboration with University of Louisville (UofL) on the design began in the spring following the third year studio, which was phase I of the project. Our studio consisted of ten architecture students and five interior design students. We were divided into five teams of three, each with two architecture students and one interior design student.

The task for each team in phase I was to study the third year designs from the previous semester and analyze them, acknowledging the strengths and weaknesses. Each team was responsible for studying two or three designs, and later presenting them to the team. The presentations allowed for everyone to come to the same understanding about each design and discuss possible design outcomes. This laid the groundwork for phase II, our first attempt at a schematic design, which is one of the first
phases of a project where the design team prepares drawings that provide a general view of the components and scale of the project.

Phase II was the longest phase of the project, lasting from January 25th to March 2nd. During this time, professor Walter Grondzik and his graduate assistant Geoff DeSmit worked on the Owners Project Requirements (OPR) for the project, essentially acting as our clients. The OPR is an explanation of the ideas and criteria that are important to the owner and is tracked throughout the design and construction of the building. Our OPR focused on a house that would be capable of being utilized after a natural disaster. A portion of the home could be delivered immediately and shelter as many people as possible. As rebuilding occurs, the home could be expanded and moved to a permanent foundation, making rebuilding of neighborhoods easier (Chiuini, et al. 3,4). Also during this phase, a construction management student, Scotty Kollwitz, contributed to the team by running cost estimations and by teaching us about photovoltaic cells.

Using the knowledge gained from analyzing the previous designs, each architecture team was tasked with generating a new schematic design that would score well in architecture and market appeal. It was amazing to see how different each design was from each team, even while working within the same constraints. During this phase, we also hosted a design weekend, where UofL students visited and worked with us to develop our designs. Phase II ended with a jury review and mock contest for architecture and market appeal. It was certainly not a conclusion to our work, but merely another starting point.
Phase III began with the conclusion of our jury review. This was, in my opinion, the most difficult phase, even though it was the shortest. Each team had put many hours into refining a design for the SD. We were then tasked with reducing the number of designs from five down to one, which proved to be a difficult process. With the help of UofL, during another design weekend, we were able to narrow the choices down. We eventually reached a consensus regarding the floor plan, and built the design from there, which began phase IV.

In phase IV, we were once again organized into teams, but all working on the same house. There were five teams, each with a specific task:

1. Digital model management. Site and exterior space design, public circulation and railings, exterior renderings, exterior structures, and specifications.

2. Interior design. Plans, sections, heating, ventilation, air conditioning (HVAC), lighting integration, bathroom design, kitchen design, interior finishes, glazing, and interior renderings.

3. Envelope. Elevations, roof design, wall sections, roof details, window design, exterior glazing types, sun angle diagrams, and sun shading studies.

4. Structure. Framing system, temporary foundations, shipping system, site logistics, assembly, structural diagrams, and coordination with the envelope system.

5. Modeling and communications. Study model, final model, computer walkthrough, and graphics coordination.

Each team worked in close coordination with each other, in constant communication.

We all worked toward an April 19th deadline for a submission of a schematic design to
the Department of Energy (DOE). At the end of the semester, the team presented our new schematic design to a jury, giving advice on how to approach the coming months of design work.

Phase I

Daniel Potash and I teamed up during this phase to research our assigned projects. An interior design student, Mollie Smith, was also in our group. Work progressed slowly, as this was the beginning of the semester and we worked to understand the goals and constraints of the competition. We were given three designs to analyze. Most designs utilized modules that would each be prefabricated, transported on a semi-trailer, and then attached together on the final site. The main reason to divide the house into modules is to allow for transportation, which becomes difficult with anything wider than fourteen feet. One of the designs that we studied was done in the previous semester by Justin Seyfert, a third year architecture student. We were both drawn to the medium-sized modules, each about 36 feet long, that were joined and then shifted along the long axis (Fig. 1). This allowed for a large, open interior floor area with two, more private spaces on each end. The design of the floor plan, however, was a problem that needed to be addressed.

This was our first experience working with a student outside of our major. Therefore, progress was slow during our initial interactions and communications. At first, our primary form of communication was email, which was slow and difficult to discuss design ideas through. Dan and I had similar schedules, which made it easy to meet in the studio outside of class time. Mollie, however, had a schedule that was far
different and unfamiliar to us. Thankfully, we found time to meet during studio time on Wednesdays and sometimes on Fridays. She agreed with us that the floor plan design was dysfunctional and needed major changes.

During presentations of the third year designs, each team gave a brief 5-minute overview of the strengths and weaknesses of the project. Dan, Mollie, and I talked about our three designs, explaining how we believed Seyfert’s design was the strongest. It was clear that there were many differing opinions on the best direction to take the designs. It seemed each team had a different “favorite” design from which to start the project. This, in my opinion, was a great thing because it allowed for the team to discuss a diversity of approaches.

**Phase II**

Using our phase I analysis as inspiration, Dan, Mollie, and I started work on a design of our own. Using the same modules from the previous design, we reworked the floor plan. Mollie’s knowledge of interior design was an advantageous contribution to this effort. We developed a plan that was completely open in the center, with the more private bedrooms on the wings to the East and West. One of these bedrooms could be doubled as an office if it was not needed as a bedroom. We found that there were benefits in the shifted modules because the voids started to define outdoor areas such as an entrance and back patio. Additionally, the kitchen would be exposed to the easterly morning light, which is a marketable feature.

With our decision to go forward with that type of floor plan, our studio professor, Michele Chiuini, advised us to start work on the section and form of the house. Dan and
I worked on form studies to see what type of design we thought would work best given the project requirements. While we explored many different roof forms and window configurations, we ultimately agreed on a flat roof with deep overhangs, inspired by the houses of Frank Lloyd Wright (Wright 23-42) (Fig. 2).

During this time, the architecture team as a whole got into the routine of keeping in close communication with the engineering team at UofL through email and regular video conferences. Video conferencing was the most useful and productive form of communication that we had aside from our face to face communication. During these video conferences, which took place during studio time usually once a week, each architecture team would present their current design and any updates since the last meeting to the team in Louisville.

The engineering team would then give feedback in the form of general advice on how to incorporate mechanical systems or even structural systems. Most of these comments were preceded by a comment that started with: “I don’t know anything about architecture, but I think...” This of course was the team’s way of being polite, a way to disagree or argue a point without offending anyone. This was something that, in my opinion, was unnecessary to the point where it became frustrating. Coming from different areas of study, we all contributed to the project individually, but we were all on the same design team, united under the same goal. Our attitude was that anyone on the team should be allowed to express his or her opinion without having reservations about whether or not it would offend someone else. I felt that the polite and formal forms of discussion became an unnecessary part of our discourse, mainly because it prevented the nature of the relationship from becoming more informal and comfortable.
The engineers seemed to like the idea of a house that used Frank Lloyd Wright's style solutions to the challenges presented in the competition and project requirements. They began to push the idea of solving multiple issues with one design move. This led us to develop a panelized limestone core wall that would also be used to hide water storage and showcase solar powered lighting (Fig. 3).

The idea to showcase the solar powered lighting stemmed from our first design weekend, when the UofL students and their professor visited BSU for the weekend of February 25th/26th. All of our time together was spent in the Architecture Building. Much of it was spent presenting new developments before the large assembled team. The other portion of time was spent with each team consulting with engineering students and then rotating, which proved to be extremely productive and inspiring (Fig. 4).

During the design weekend, I found it much easier to discuss the design and understand feedback from the engineers. We didn't have to wait until the next scheduled video conference to progress with the design. Everything could be clarified in multiple ways, which led to a better understanding for everyone. Dan and I became comfortable explaining our design intent and direction due to the frequent discussion. This, in turn, gave us a better understanding of what we needed to work on with our design, such as the mechanical system. The engineering students helped us choose the best possible HVAC system for our house, something that we would not be able to do on our own. In the end, we ended the design weekend extremely tired but with a much more refined design and direction in which to move forward.
After the design weekend, the usual routine ensued. We conducted a video conference once a week, each time presenting to the engineers and receiving feedback. We were working towards our deadline for the presentation that took place on March 2\textsuperscript{nd}. We had a large list of required drawings and specifications that had to be incorporated into the presentation. After several long days and nights, Dan and I were able to put together a presentation we were proud of. On March 2\textsuperscript{nd}, we presented before a panel of professionals coming from inside and outside of the college. Their objective was to judge each of the five house designs based on the SD’s architecture and market appeal competitions. After hearing the feedback and scores from the panel, it was clear that all houses needed much more refinement and improvement before they would be considered acceptable. The biggest criticism that Dan and I received was that our design did not convey the idea of the solar house. This was due in part to the flat roof, which hid the solar panels from sight and in a position that makes them less efficient than they would be on a sloped roof. Dan and I felt that a flat roof would be more versatile for a solar house. While panels on a flat roof are less efficient, they allow the house to face any direction, something that a sloped roof would not be able to do. Another criticism was that our design had a FLW appearance that made it unique and therefore unnecessary when rebuilding a neighborhood after a disaster. In other words, it was unoriginal. After this, we were given some time to make small changes to our design, but it didn’t change much as we moved into the next phase.

\textbf{Phase III}

After our jury review, it was obvious that none of the house designs were significantly better than the others. This made it impossible for us as a team to choose
one design to move forward in the competition. Professor Chiuini was also unsure about how to narrow the five potentially successful designs down to one. We decided to wait until our second design weekend, when the architecture team visited the engineering team at UofL, to begin to narrow down our choices.

Unfortunately, Dan and I were not able to attend this design weekend. Upon returning, the other architecture students informed us on what had taken place. During the design weekend, the entire team decided it would be best to distill each design down to the basic floor plan. From there, we could judge each design based on the efficiency and functionality of the plan. In the end, they were able to narrow their choices down to two house types. Each house utilized one long module with a “wet” core of the home, meaning it contained all the plumbing necessary for the home (bathroom and kitchen), and one short module for additional space.

The team of architecture and interior design students was then tasked with choosing one of the two floor plans. Since there was obvious support for both choices, we decided the best course of action was for everyone to vote for the one he or she thought was best. Although it was close, one floor plan received the majority of votes and was therefore our starting point for the house. Although both floor plans were similar; the winner had a separately defined dining room and more opportunity for storage space, making it the better choice (Fig. 5).

This was the first time during the semester that the team as a whole was forced to come together and make decisions that would remain permanent throughout the rest of the competition. During the discussions before the voting, it was clear that there was a division among the group in respect to which floor plan was favored. This was the first
time I felt tension among the group as we debated which floor plan was better. The disagreement on which floor plan to choose boiled down to one’s opinion about a separate dining room versus an integrated dining/kitchen space. This was cause for some concern because we still had to work together as a team even after we chose the floor plan. After the vote, I could see that the supporters of the other plan were upset. Fortunately, they did not let that hinder progress and continued to make a positive contribution to the group.

**Phase IV**

Phase IV began after we chose our final floor plan layout. We reorganized into five different teams, each with our own aspect of the design and general presentation as noted earlier. I became one of three members of the envelope team. We dealt mainly with the elevations, which included work on the roof form, window placement, materials, shading devices, and general wall construction. Our work, of course, had to be developed with close collaboration with the other groups, mainly the exterior and interior design teams.

A big challenge that all of us faced was learning to use Revit, an Autodesk software used for architecture. This program is required by the SD rules to be used to produce all the drawings for the house. Revit is a building information modeling software that allows multiple people to work on the same file simultaneously. Many of us had never used the program before this time, requiring us to learn it before we could be productive. We consulted with the interior design students, who had previous experience with the software, and at this point a number of Revit workshops were set up.
as part of the studio to help us learn. These workshops were effective and pretty soon everyone was comfortable using Revit.

Progress, even after learning the new software, was slow for several reasons. First, no single team, or person, was in charge of making the final design decisions. This resulted in many suggestions and productive conversations, but reluctance to put anything into the model. Second, much of the team responsibilities overlapped. For example, the window design and placement was officially part of the envelope team's responsibility, but ultimately affected other teams, such as the interior design and exterior. This, again, resulted in a reluctance to make final decisions as a team in fear of contradicting another team's work. Since no single individual had authority over the project decisions, a difference of opinions resulted in a pause in progress until it could be agreed upon. Gradually, the house design progressed to the point where we could create all the necessary drawings and images suitable for our schematic design proposal. Each team was responsible for their own drawings, which, when compiled formed a complete presentation.

The semester ended with a presentation of the current house design to a jury with many of the same professionals from the phase II review. The feedback was much more positive than the earlier review. They found the house to be much more original, functional, and cost-effective than the previous designs. This was a great way to finish our semester of work on the SD, as everyone was proud and excited for the future of the design (Fig. 6).
Discussion

As an architecture student, the semester working on the SD was vastly different from my experience during other semesters. I attribute this unique experience to the pedagogy of architectural education when compared to the design process in the professional world. There is a large disconnect between the typical design process in an undergraduate architecture studio and the design process in an architecture/engineering firm. Although I do not have much direct experience working in an architectural office, I have learned enough from other students and practicing architects to have an informed idea about what it is like.

I want to make it clear that I believe that CAP at Ball State University has a great architecture program; I am merely talking about architectural education in general. In a typical architecture studio, most projects are done on an individual basis, with all the work done by one person throughout the whole design process. This is effective in teaching the student about the fundamentals of preliminary design, structure, schematic design, and many other important skills. However, a critical skill that is not learned in this process is working well with a group of peers.

Working with peers and even those outside of the architecture profession is an integral part of working in an architecture firm. Many students find it extremely uncomfortable initially during their first internship with a firm because they do not know what to expect. They usually find it is much different than what they are used to doing in studio.

The diversion from the typical studio experience is what made the SD semester so unique and valuable. The skills we learned while working in an interdisciplinary
group will be useful in the future within the profession of architecture. I learned about the importance of respect among a group in which everyone is entitled to their opinion. It is important to ensure that everyone can express their opinion without fear of offending anyone. I also learned about the engineering profession as it relates to architectural design. I quickly found out that the issues they focus on are completely different from what I am used to. This was beneficial as it forced me out of my framework of thinking in order to solve the problems they presented, such as the HVAC system and the transportation assembly.

Architectural education is constantly under analysis and evolving as the profession changes. While studio courses are extremely effective at teaching architectural design fundamentals, interdisciplinary experience is something that should be incorporated into the curriculum. It is the only way give students experience handling real world situations with other professions. The SD was simply one way to incorporate other disciplines within our studio. It requires a significant time commitment from the teaching faculty to devote time out of class for meetings coordinated with the other groups. Schedules across different majors seldom align. These are challenges that must be overcome in order to provide an interdisciplinary experience for students. In the future, I hope to see more opportunities such as the SD available to architecture students. Not only is it a great way to learn about clean energy in architecture, but it provides training that will be used in our future careers.
Fig. 1. The floor plan of our initial design. We were drawn to the open area in the center and the negative spaces formed at the two corners.
Fig. 2. One of our first exterior renderings. The clerestories and deep overhangs were inspired by FLW house designs.

Fig. 3. An exterior rendering that clearly shows the limestone core wall idea. Another row of clerestories was added above the floor-to-ceiling windows to give the illusion of a floating roof.
Fig. 4. During the first design weekend (Feb. 25/26) engineering students from UofL worked with architecture students to run an energy analysis and develop plans for HVAC systems.

Fig. 5. The floor plan was chosen by the team because of the defined dining space and extra storage.
Fig. 6. An exterior rendering of the design at the end of the semester. One of the unique features of this house is the roof lines, which are created by a combination of the trellis and sloped roof.
Works Cited

