The Solar House in Washington DC used with permission of Stefano Paltera / DOE Solar Decathlon 2005

THE DEVIL IS IN THE DETAILS The 2005 Virginia Tech Solar House

The relationship of the architectural details with the central architectural idea

Brett Greer Moss

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of **Master of Architecture.** Thesis defense took place on the 15th of October in the year of 2005 in the city of Washington D.C. during the 2005 Solar Decathlon Competition.

Key Words
Solar Decathlon, Solar House, Sustainability, Details, Translucent

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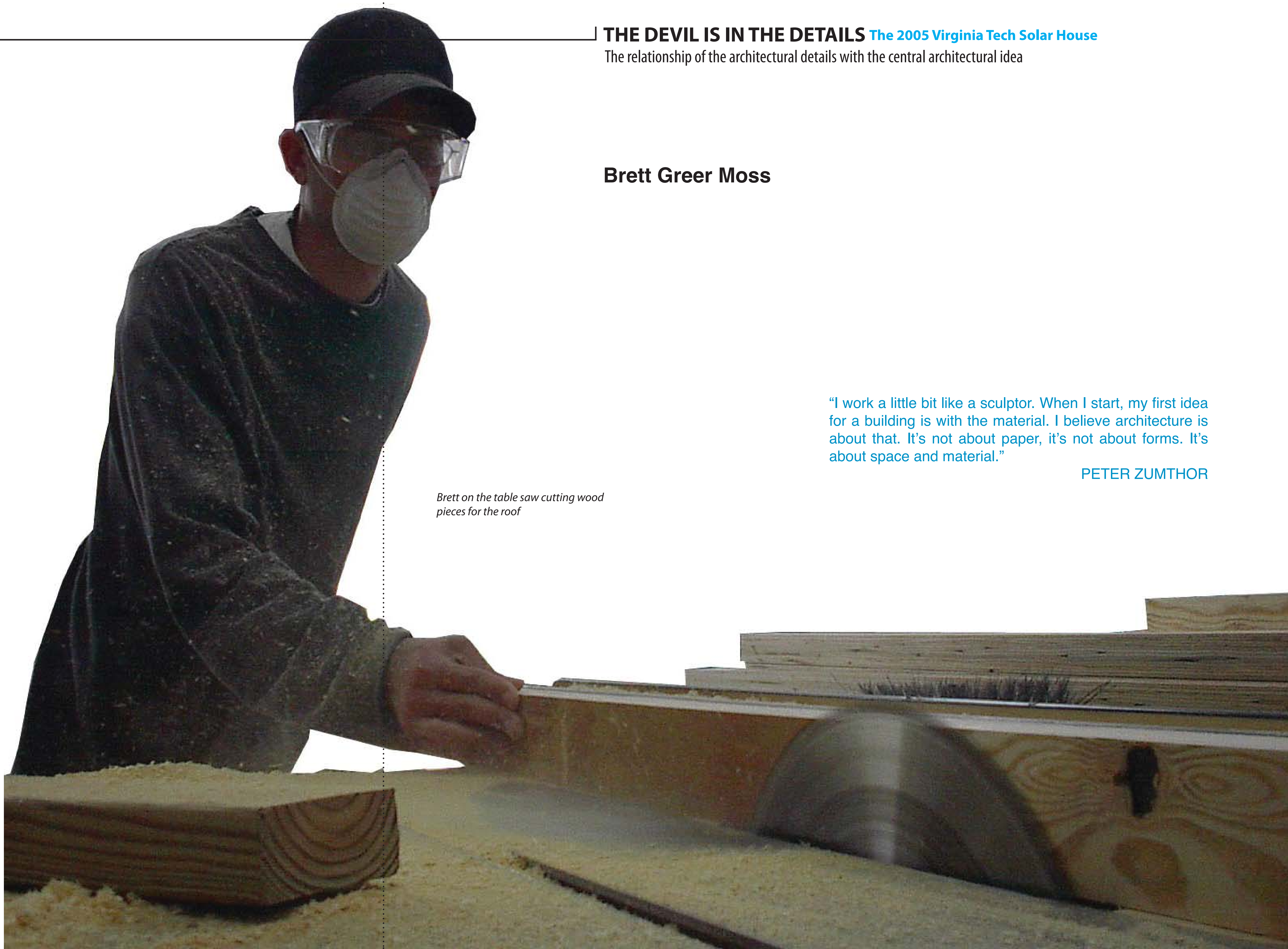
Abstract The central idea of the 2005 Virginia Tech Solar House was to celebrate its solar aspects while integrating the engineering systems and the architecture into a single entity. Through the process of design and construction, the relationship between each detail and the overall architectural concept became evident. Highlighting four specific details to illustrate such intimate relationship, this study shows the importance of carefully working through each detail to remain faithful to the original design without any major compromise.



Brett on the table saw cutting wood pieces for the roof

"I work a little bit like a sculptor. When I start, my first idea for a building is with the material. I believe architecture is about that. It's not about paper, it's not about forms. It's about space and material."

PETER ZUMTHOR

Bryan Atwood and Tom Shockey making precise cuts

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INTRODUCTION THE VIRGINIA TECH SOLAR HOUSE 2005

* The Solar Decathlon is an international competition held in Washington DC every two years by the U.S. Department of Energy and the National Renewable Energy Laboratory that challenges top universities to design, build, and operate solar powered houses that are cost-effective, energy efficient, and attractive. The purpose is to educate students and the public about clean-energy products, to create awareness to the public of houses that combine energy-efficient construction and appliances with renewable energy systems that are available today, and to provide participating students with unique training that prepares them to enter the

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** Text summarized from the DOE Solar Decathlon website - refer to references*

nation's clean-energy workforce. The competition consists of ten events, architecture, dwelling, documentation, communications, comfort zone, appliances, hot water, lighting, energy balance, and getting around, which are judged during the three-week exhibition to determine an overall winner. *

** The process of design and construction involved individuals with varying degrees of skill, expertise, and background. Teamwork in conjunction with strong student leadership was required. Problem solving, information flow and integration, alternative generation, ideation, innovative troubleshooting and testing are all part of an experience where the consequences of decisions were real and verifiable. This design/build, hands-on learning experience not only required innovative design strategies; it necessitated a program of funding through corporate and industry contacts. As part of this effort, students in collaboration with architects and engineers, surveyed manufacturers and suppliers to procure materials that were sustainable, energy conscious and a qualitative improvement for the residential environment.

The Virginia Tech Solar House is driven by a multidisciplinary approach that challenges research through application. It harnesses the tension created by the dualities of calculation and intuition; technological innovation and architectural expression; optimized performance and sensible materials; and between physical fact and psychic effect. Simultaneous consideration of technology and architectural content has guided the identity of the house. Every decision involving quantitative criteria was measured in terms of its contribution to spatial quality. New forms have been derived from technical considerations, and enriched patterns of daily life find expression in a celebration of energy awareness and resource conservation.

The growing need for effective utilization of resources places greater emphasis on architectural form that harnesses the sun and addresses local climatic conditions. These new forms must evolve from an approach of systems integration that maximizes the benefits from heat, light and airflow. This project pushes existing paradigms by proposing an architecture that celebrates solar energy while obtaining a high level of system integration.

Materials that are renewable, recyclable and reflect low embodied energy can be used in combination to decrease the level of adverse environmental impact. Design decisions and material selection aim to reduce indoor pollutants, minimize global warming, reduce waste, include recycled content, represent low embod-

The 2005 VT Solar Decathlon received the following awards.

-1st Place in Architecture
-1st Place in Dwelling
-1st Place in Day lighting
-1st Place in Electric lighting
-4th Place Overall
-2006 Honor Award from the Virginia Society of the American Institutes of Architects
-American Institutes of Architects Presidential Award for best Design
-National Council of Architectural Registration Boards Honorable Mention for the Creative Integration of Practice and Education in the Academy

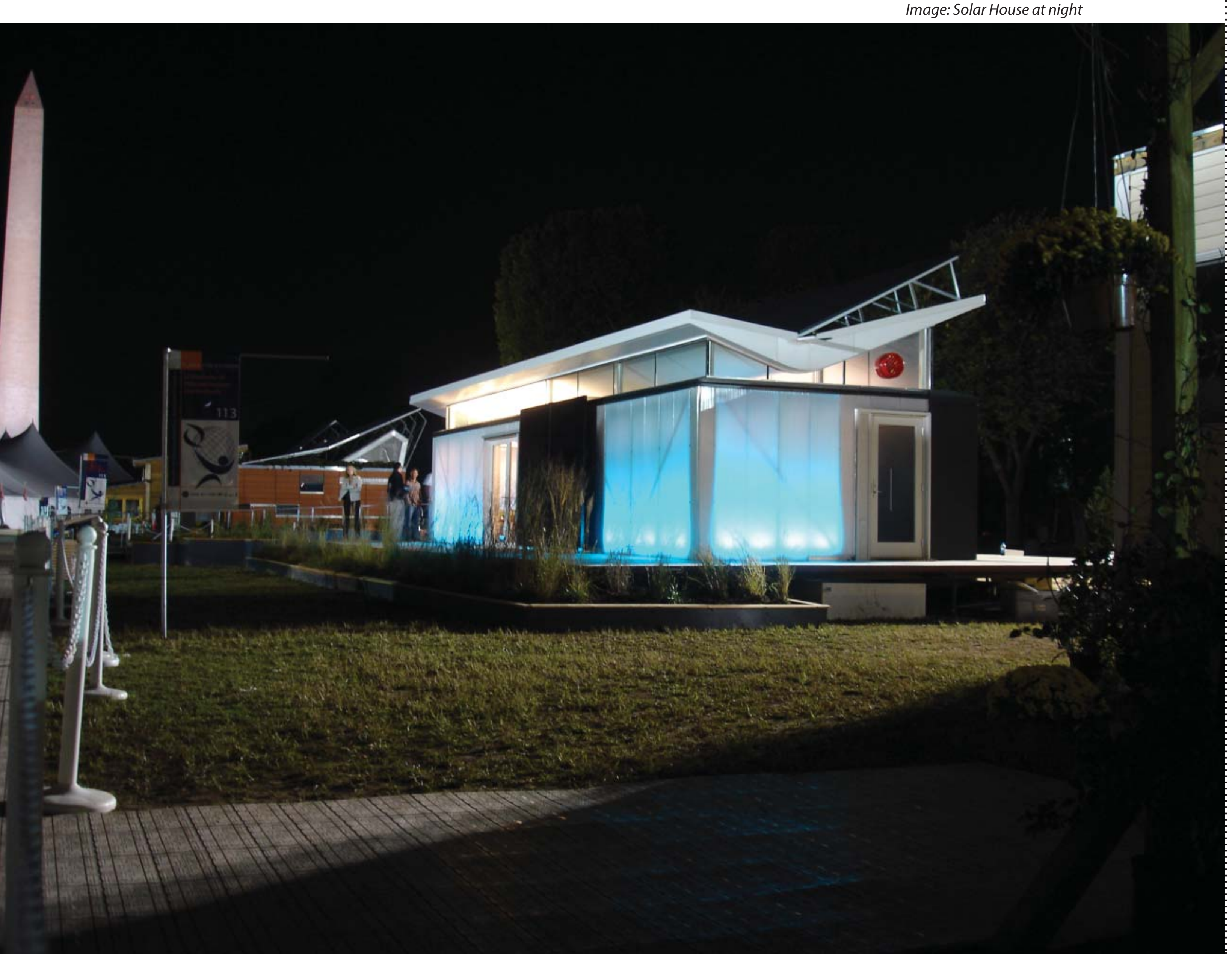
*** Text summarized from the Virginia Tech 2005 Solar Decathlon website refer to references* ied energy in manufacture and harvest, limit destruction to habitat, and rapidly renew.

How to be sustainable without sacrificing material integrity? In the end, it has to be beautiful. **

In order to select the design that would serve as its 2005 Solar Decathlon competition entry, Virginia Tech held a multidisciplinary two-week competition that resulted in my team's proposal being selected among more than 60 submissions. For the next two years, we were to lead a team of students in the development and construction of a solar house.

Through the process of designing and building the 2005 Virginia Tech Solar House, I was able to study the relationship between each detail and the overall architectural concept. By overall concept I mean the central idea of the architecture, the specific impression that the architect wants to create within the limits of external factors and utilitarian functions of the structure. A detail is an isolated piece or part of the architecture that can be complex and made up of many pieces, or simple and made up of few pieces. This paper discusses the importance of scrutinizing each detail in order to maintain the integrity of the overall concept. In other words,

Image: Solar House at night



the more one carefully studies and thinks through each detail, the more faithful one can remain to the overall concept. Conversely, the less a detail is thought through, the more likely it is to cause problems at any point in the process and thus compromise the integrity of the overall concept.

To illustrate this argument, I have selected four specific details that were significant to the composition of the architecture, and for which it was necessary to invest a great amount of planning and effort before coming up with a result. But before discussing the specific details and their relationship to the overall concept, it is necessary to lay the ground, as it were, by providing some background on the development of the overall architectural concept, the different issues that presented themselves and the choices with which the team responded to them, followed by a description of the main elements of the house.

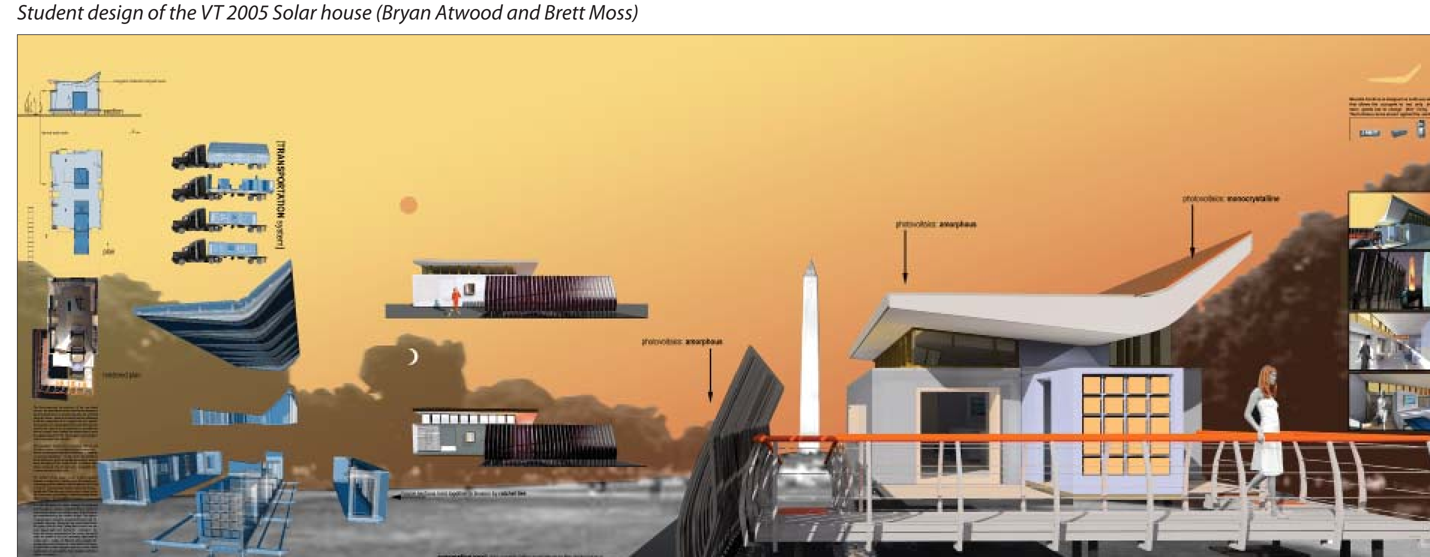
The original idea was born in October of 2003 during a two-week interdisciplinary student competition. The idea was submitted for the solar house design competition in collaboration by a group of four students

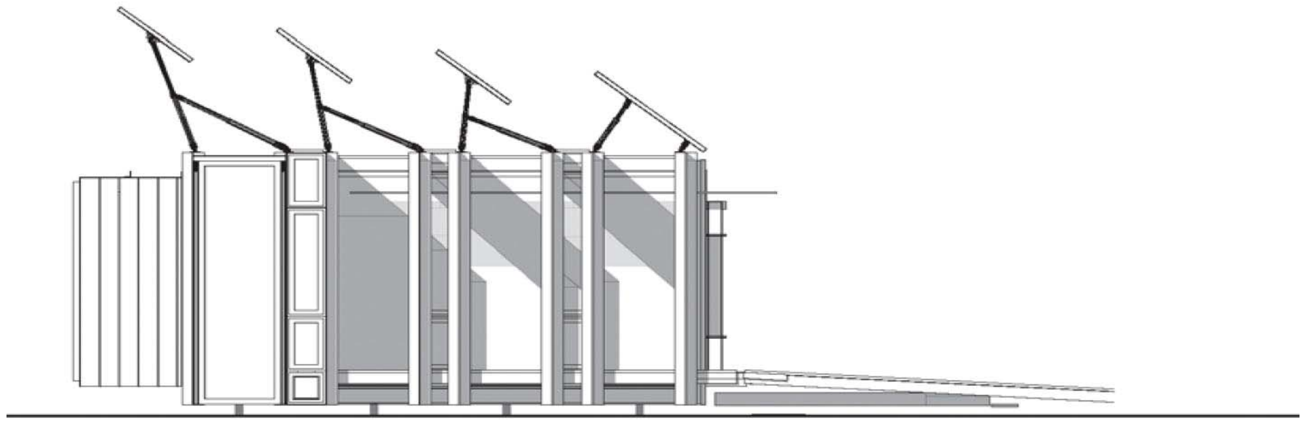
[Nathan Werner, Luis Velez, Bryan Atwood, and Brett Moss]

After many days of intense brainstorming our team decided that, in order to meet all the challenges of the competition, the 2005 VT Solar House should highlight and celebrate its solar aspects and the energy it produces, while integrating the engineering systems and architecture to constitute a single entity. This became the central idea or overall architectural concept of our design, from which all other decisions would spring and to which we would strive to remain faithful throughout the entire process.

These decisions were in part the result of a careful study of past experiences, such as the Kunsthaus in Bregenz, Austria and Virginia Tech's own 2002 Solar House. Peter Zumthor's concept is to allow an even amount of natural light to enter

Student design of the VT 2005 Solar house (Bryan Atwood and Brett Moss)





Elevation Drawing of the 2002 VT Solar House

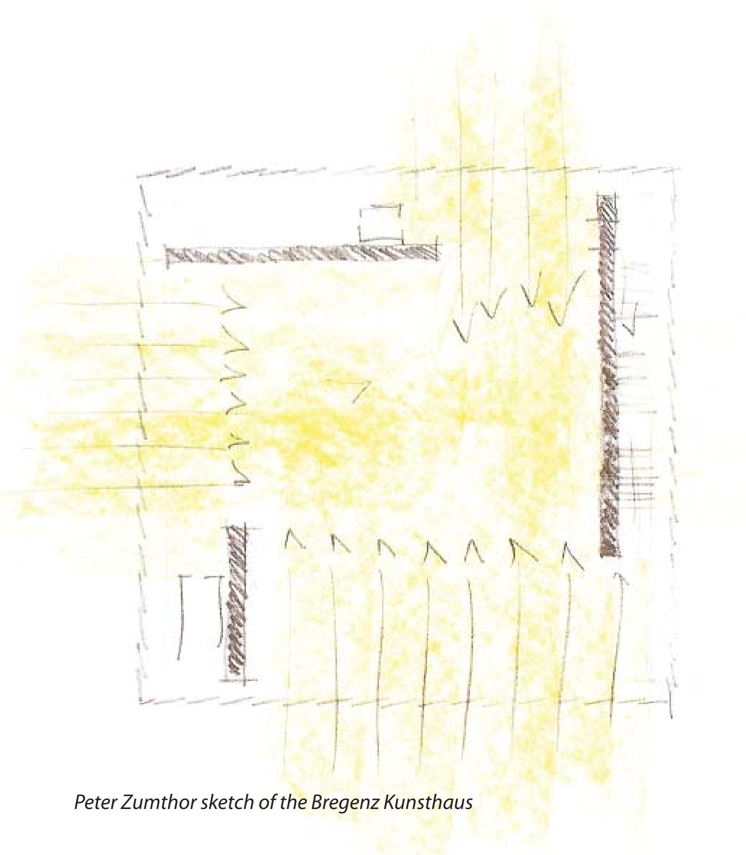
through the translucent walls and into the museum's exhibition spaces. At night, the building becomes an iconic lantern for the city of Bregenz. Zumthor designed a system that is able to control the amount of light with automatic shading systems above the interior ceilings. The ideas of even light and a translucent skin became the most prominent aspect of the architecture for the 2005 VT Solar House. But the chief source of inspiration throughout the design and construction process was the 2002 Virginia Tech Solar Decathlon House. This house has many merits in the design decisions but this design approach had a profound impact on the amplification of the engineering systems within the architecture. A beautiful house in its own right, the 2002 VT Solar House is rather a machine-like building where the engineering systems take center stage, whereas the 2005 Solar House would have to provide a seamless integration of the engineering systems with the architecture and thus create a unified impression. The 2002 VT Solar House became a learning tool that helped us understand the relationship between the systems and the architecture, and allowed us to avoid repeating many of the problematic issues that its team experienced.

The 2002 VT Solar House

The 2005 VT Solar House

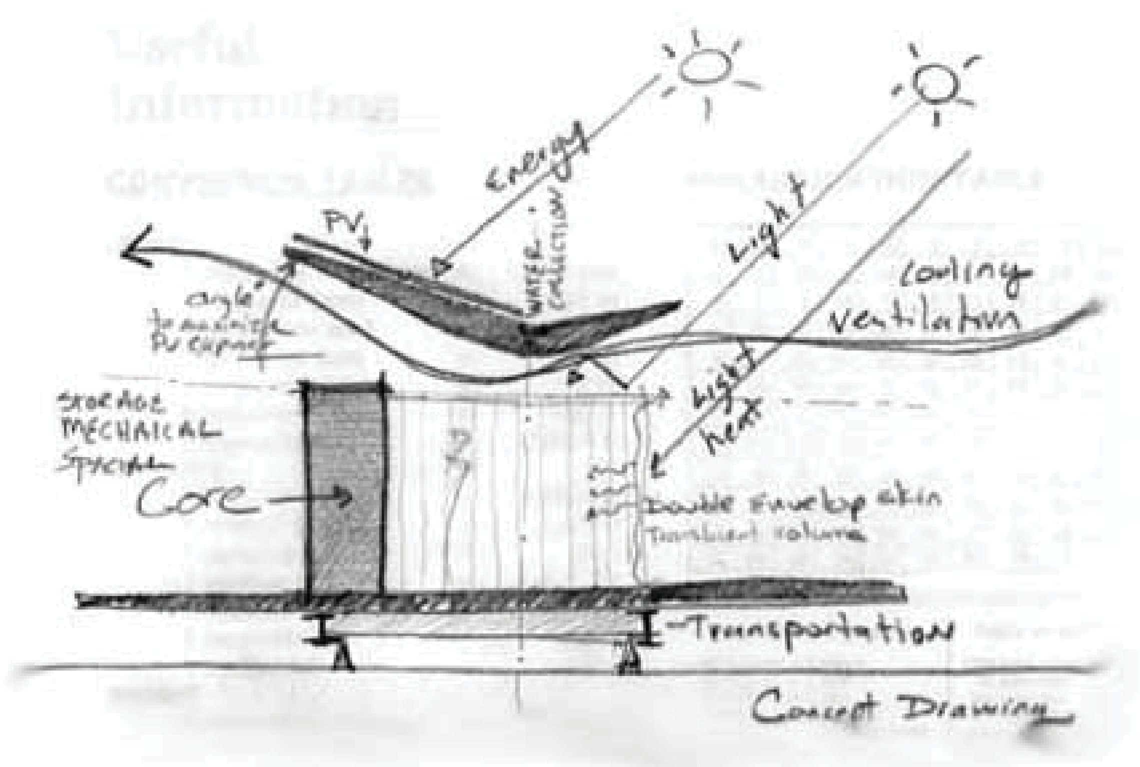
Night Image of Bregenz

Image of the Bregenz Kunsthaus



Peter Zumthor sketch of the Bregenz Kunsthaus

Conceptual sketch Below is a conceptual sketch that I made which displays some of the external factors that we considered during the development of the solar house.



Conceptual Sketch

THE ISSUES AND THE RESPONSE THE 2005 VT SOLAR HOUSE

THE DEVELOPMENT OF THE DESIGN

While architecture, the art of building, can be defined as a structure that provides space, formed as a result of a combination of external factors, utilitarian functions, and the relevant choices made by the architect, sustainable architecture has the specific objective of maximizing functionality and efficiency. In addition, if sustainability refers to the ability to last, it is clear that sustainable architecture should also provide aesthetic value, for the more an object is valued, the more reasons that it will be cared for, resulting in a longer life.

In the case of the 2005 VT Solar House, there were many such external factors, utilitarian functions, and choices made by the team of architecture students, all of which had a large impact on its design. Among the most important were energy efficiency, transportation and structure, site and orientation, lighting and materials, livability and quality of construction and space, exhibition and research, and the idea of integration and celebration of a solar house. These issues are further discussed below.

Energy Efficiency

The house needs to reduce the amount of energy consumed by integrating passive solar design strategies into the architecture. The selection of materials must be limited to those with low embodied energy, longer life expectancy, and ease of recyclability. The house must integrate innovative active systems that reduce the load of energy consumption while maintaining a comfortable indoor environment.

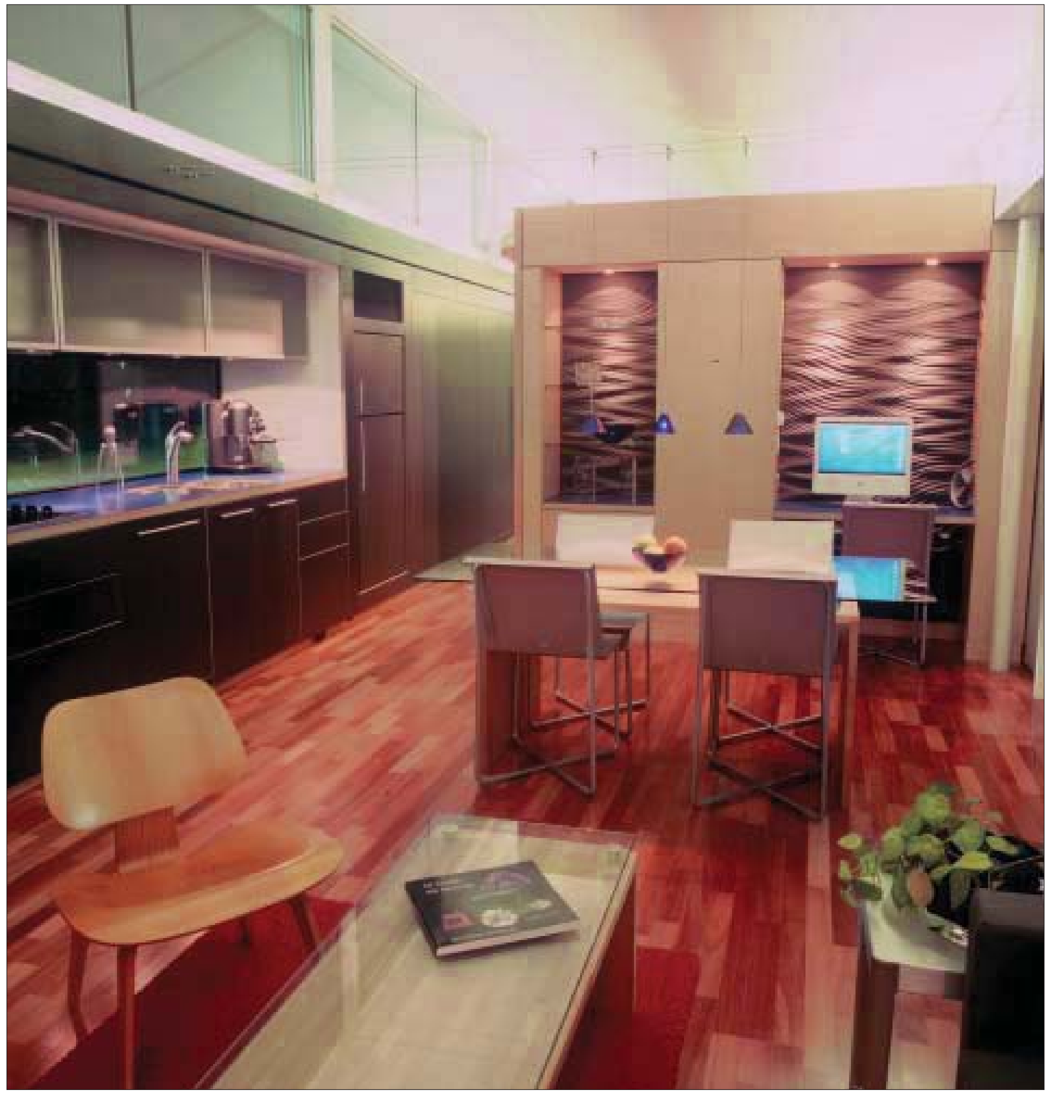
Transportation and Structure

Transporting a house hundreds of miles on a highway is a challenging task. Height restrictions for clearance under bridges, structural loads from many different lateral and gravitational forces, width and weight restrictions—all need to be taken under careful consideration in the design and structural development.

Site and Orientation

The orientation of the house on the site is one major factor that will determine the final form of the building. It is important to understand the sun and the solar geometry throughout the year based on the location of the house. The house must respond to the sun in many ways. The roof must be at the optimal angle to maximize the amount of energy that the photovoltaic array can receive during the year. The roof and overhangs must be able to provide shade in the hot summer months and allow the sun's heat to enter the spaces in the cold winter months. Even the southern wall could be used as an additional source of solar energy collection during the winter.

The orientation of the house in relationship to the wind is extremely important. During the winter months, the northern part of the house must be protected from the cold winds, and in the summer it must allow the cool winds to cross through



Interior of the house at night

The house being transported

the spaces. Rain needs to be collected by the roof and purified by natural landscape to be reusable. Site and orientation also affect perception: the interior and exterior of the house can be manipulated to allow a small space to seem much larger and better connect to the surrounding environment.

Lighting

The creation of a beautiful and functional space begins with the material light. In order for the occupants of the house to function efficiently and reduce the use of electric lighting, both natural and electrical lights had to be carefully studied. A space evenly lit by the sun in the day and electricity in the night will reduce the consumption of electricity while increasing the quality of the space.

Livability

The quality of the space and materials ultimately produces an optimized, livable home. The value of the home depends on these qualitative aspects, which give the owner the incentive to care regularly for the house that will eventually sustain longer in life. An efficient plan that provides generous space within a small footprint is necessary. A coherent relationship between the rooms is needed to provide maximum efficiency of function within the space. The volumetric spatial perception of the home, the selection of durable materials, and the quality of construction must all be considered in order to create comfort and sustainability.

Exhibition

The main reason for this house to exist is to bring awareness to the public regarding renewable energy and energy efficient architecture. Thus the house needs not only to be a cutting edge home but also to function as an exhibit. The layout of the house must be designed with the understanding that thousands of people will be walking through and learning about the design and systems.

House during exhibition

View from line

In response to these issues, the team came up with the following specific choices:

- **A translucent wall** assembly that transmits beautiful natural light and delivers high insulation and sound absorption value.
- **Tunable walls** that control moisture, temperature and light transmission while allowing any desired color, no painting required.
- **An efficient plan** that offers spatial generosity.
- **Architectural form** that subsumes the connotations of technology with elegance and grace.
- **An integral roof/ceiling** that expresses the collection of energy provides intimacy and psychologically expands the volume of the house past its small footprint.
- **Night time identity** that symbolically radiates back the energy collected during the day.
- **A surrounding deck** that links inside and outside, establishes presence on the site, and serves as a structural element for transportation.
- **Radiant floor** heating throughout the house, quiet, no moving air, the highest quality heat.
- High pressure heat pumps that efficiently heat water for the radiant system.
- **Sustainable materials** that contribute to the quality of space and healthy environments.

The process by which the responses outlined above helped achieve spatial generosity, maximum efficiency, functionality, and beauty can be better appreciated by a description of the main four elements of the house: the platform, the cores, the translucent walls, and the floating roof.

House on its way to Washington DC

ELEMENT ONE THE PLATFORM

TRANSPORTATION, THE FOUNDATION, THE STRUCTURE, THE ENGINEERING

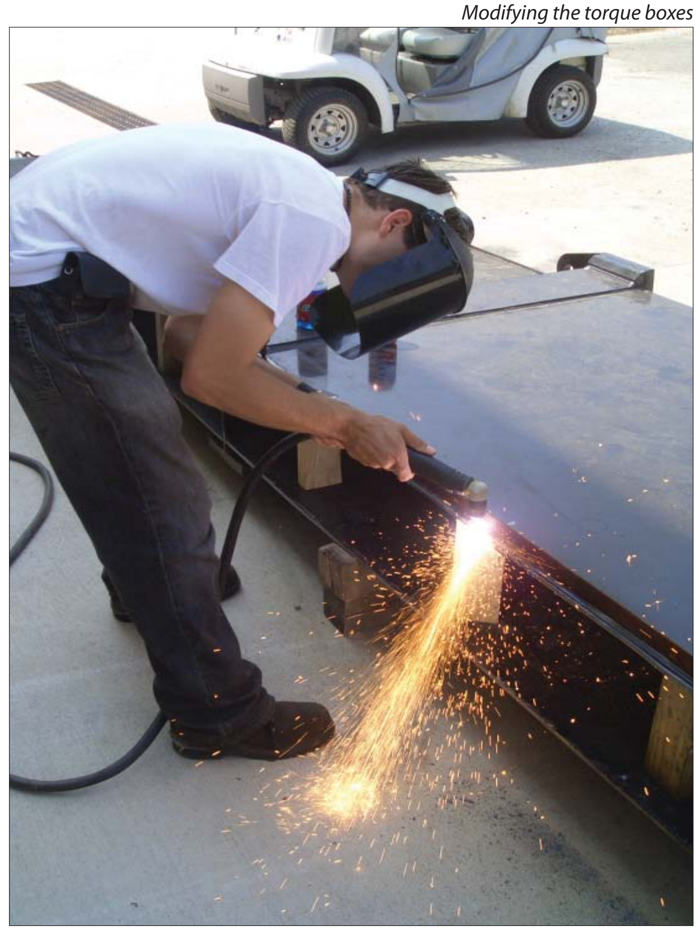
An architectural moment happens as a structure touches the earth. How the 2005 VT Solar House was to make this connection as a mobile home was to be a difficult and innovative task. The house touches the earth as if it was floating on a plane or platform. This platform is designed to connect the interior spaces to the exterior with a wrap-around deck. Further, its integration into the structure and its capability of mobility are absolutely phenomenal.

Mobility and integration is the main focus for the design of the platform. Like many mobile homes, the concept of the trailer chassis as the actual floor of the solar house eliminates the problematic issue of lifting a house on and off a trailer, which creates awkward stresses upon the structure and the need for large machinery. However, two major factors separated this house from the transportation concept of a mobile home—height and weight.

With a house that weighs nearly three times the average weight of a mobile home, the trailer chassis and wheels have to be considerably larger and stronger. Since the solar house has 12-foot high ceilings, it must be transported as low to the ground as possible in order to clear bridge heights along the highway. For this reason, a lowboy type trailer concept was explored and adopted for the house.

An example of a low-boy trailer chassis

Modifying the torque boxes



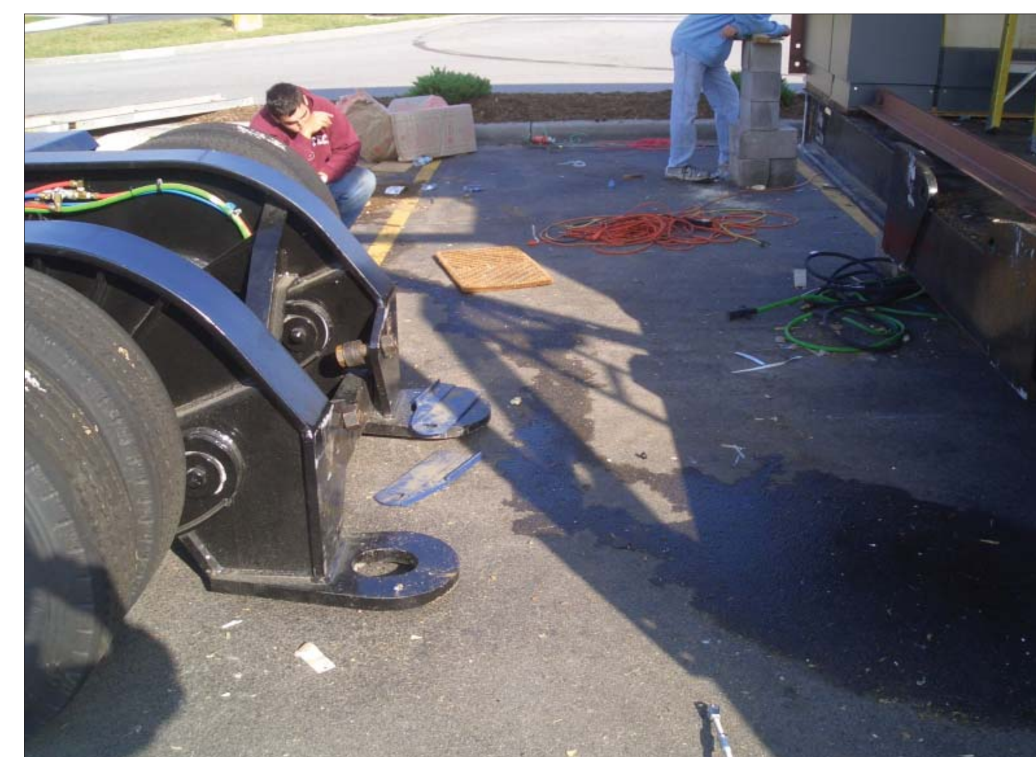
A lowboy trailer, which travels six inches off the ground, can transport extreme amounts of weight up to 12 feet in height that normal trailers cannot. However, a lowboy trailer has large wheels in the rear and a large gooseneck tongue in the front, which from a livability standpoint is problematic to have permanently attached to a house. Further, a lowboy trailer is able to transport heavy loads because of the camber, or arched shape, in the trailer that considerably strengthens the chassis. However, an arched floor in the house was not possible, which made it clear that a great amount of ingenuity was necessary to develop a structure that has the ability to transport the house low to the ground and flat.

In order to adapt the lowboy idea to our needs, we came up with two solutions. The first is detachable rear axles and a front gooseneck tongue for the trailer chassis. Detachable gooseneck tongue trailers are common in the trucking industry, but a detachable set of rear axles is not. With the help of the Virginia Tech engineering department and the engineers of a trailer manufacturer, this idea was developed and implemented for the solar house. The engineers developed two large steel torque boxes that could withstand the massive loads at the front and rear of the trailer. The boxes are 14 feet wide, 4 feet deep and 12 inches thick, and are welded to the main steel I-beams of the chassis. The front torque box has a special connection for the gooseneck tongue, and the rear torque box has a special bolt and pin connection for the rear axle system. The axle system consists of two axles and eight wheels, and has air bags that are able to adjust the height of the house at the rear. The detachable gooseneck tongue also has a hydraulic system that can adjust the height of the house at the front.

The second solution was a chassis that could carry a heavy load without having a cambered trailer. This resulted in the design of an 8-foot tall steel truss system that ran above the two main I-beams of the chassis. These trusses essentially cre-

Rear axles being prepared for attachment

Gooseneck tongue being attached to the house

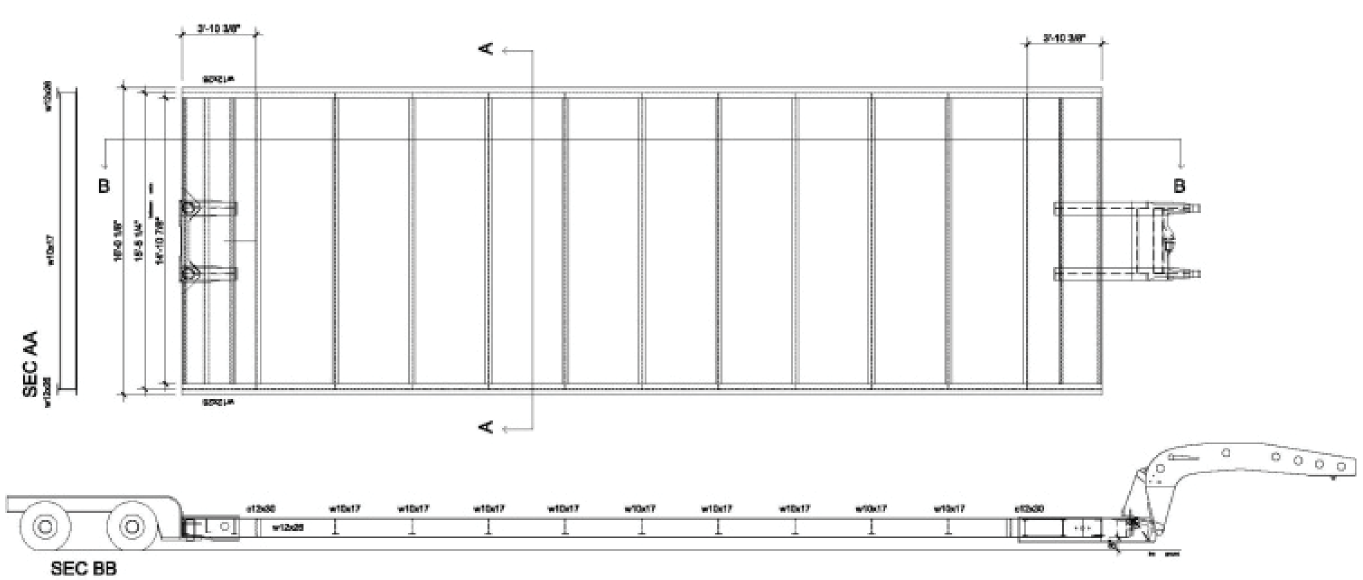


Rear Axel fittings

House in transport

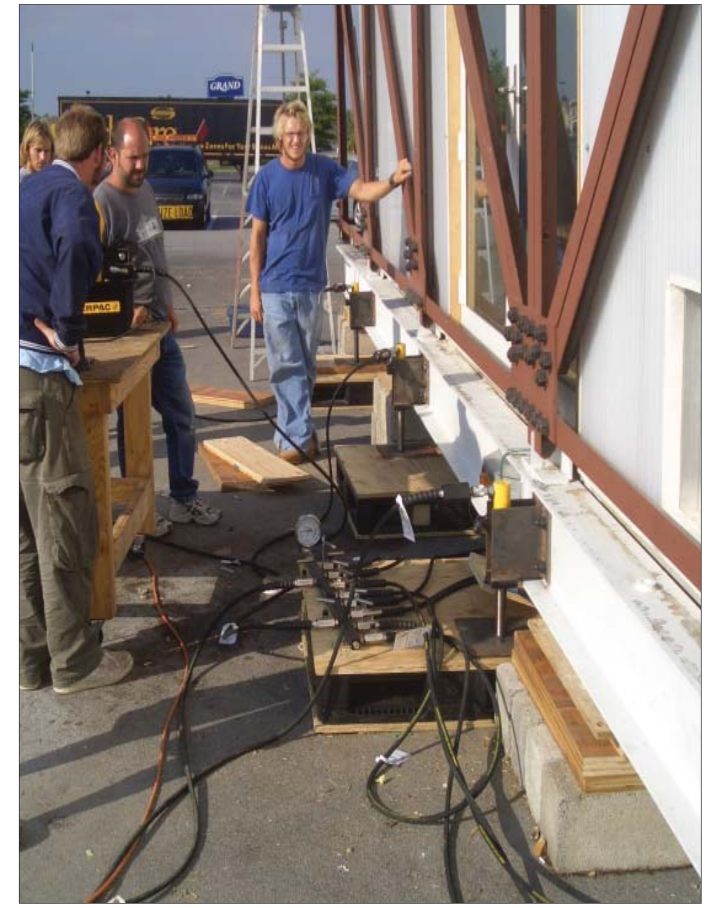
The Moment of truth I remember the first time we moved the house and we prayed that no major structural problems would arise. Below is a photo of the first few minutes that the house was transported. We drove the house about ten miles down the road to a Lowes parking lot where we would complete the construction for the next month before heading to Washington DC. This ten-mile drive was a test to see how the structure would perform and to study the effects the deflection and movement had on the structure. One noticeable effect was that the metal cross strapping inside the translucent walls were either pulled in tension or warped due to compression; however, the structural design worked beautifully and there were no needs for further modifications.

Truss system being raised by students - no machinery needed



Plans of the custom built chassis

Jack system



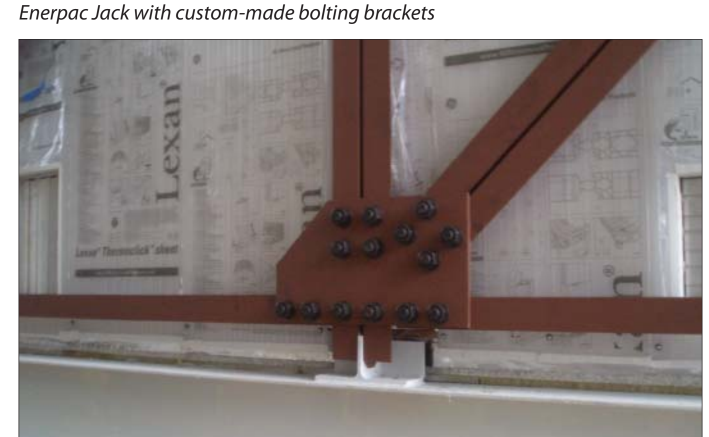
ate a 48-foot bridge, minimizing any deflection caused by the house's 50,000 pounds of weight moving at high speeds on the highway.

Once the house is in place, it sits on a system of ten hydraulic jacks that are integrated onto the main I-beams of the chassis. The jacks are linked to a main controller that can easily and safely level the house. Once the house is on its hydraulic jacking foundation, the truss system is no longer needed to structurally suspend the house from the axles to the tractor. It can now be used for its additional function as part of the exterior deck.

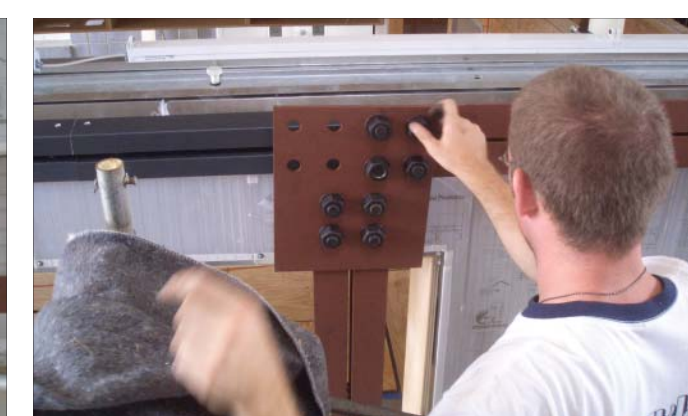
The truss system is designed to pivot 90 degrees to provide the structural frames for the house's exterior platform deck. The exterior deck is made up of many prefabricated 8-foot triangular cedar planks. These are placed flush between the chords of the truss, which provides a smooth and ADA compliant transition from exterior to interior. Furthermore, it creates a thin and sleek platform as well as it provides an opportunity to express the importance of the steel trusses in the integration of the design.

Above the main chassis are the actual interior spaces of the house. Directly above the steel I-beams of the chassis is a layer of 3-1/2 inch structural insulated panels, or SIPs. The SIPs provide added rigidity to the chassis and floor, as well as an excellent insulation barrier for the interior floor of the house. Above the SIPs is a radiant floor system, which is an efficient heating system that is integrated into the floor throughout the house. Hot water is pumped through different zones of the house which then heat aluminum plates that distribute the heat efficiently up through the floor. The finish floor is a eucalyptus wood floor chosen because of its relatively light weight, environmental sustainability, and beauty. The eucalyptus tree is grown on managed plantations in Brazil, and is a fast growing tree that is harvested every five years, which helps to preserve

Enerpac Jack with custom-made bolting brackets



Pivot connection and gusset plate of the truss

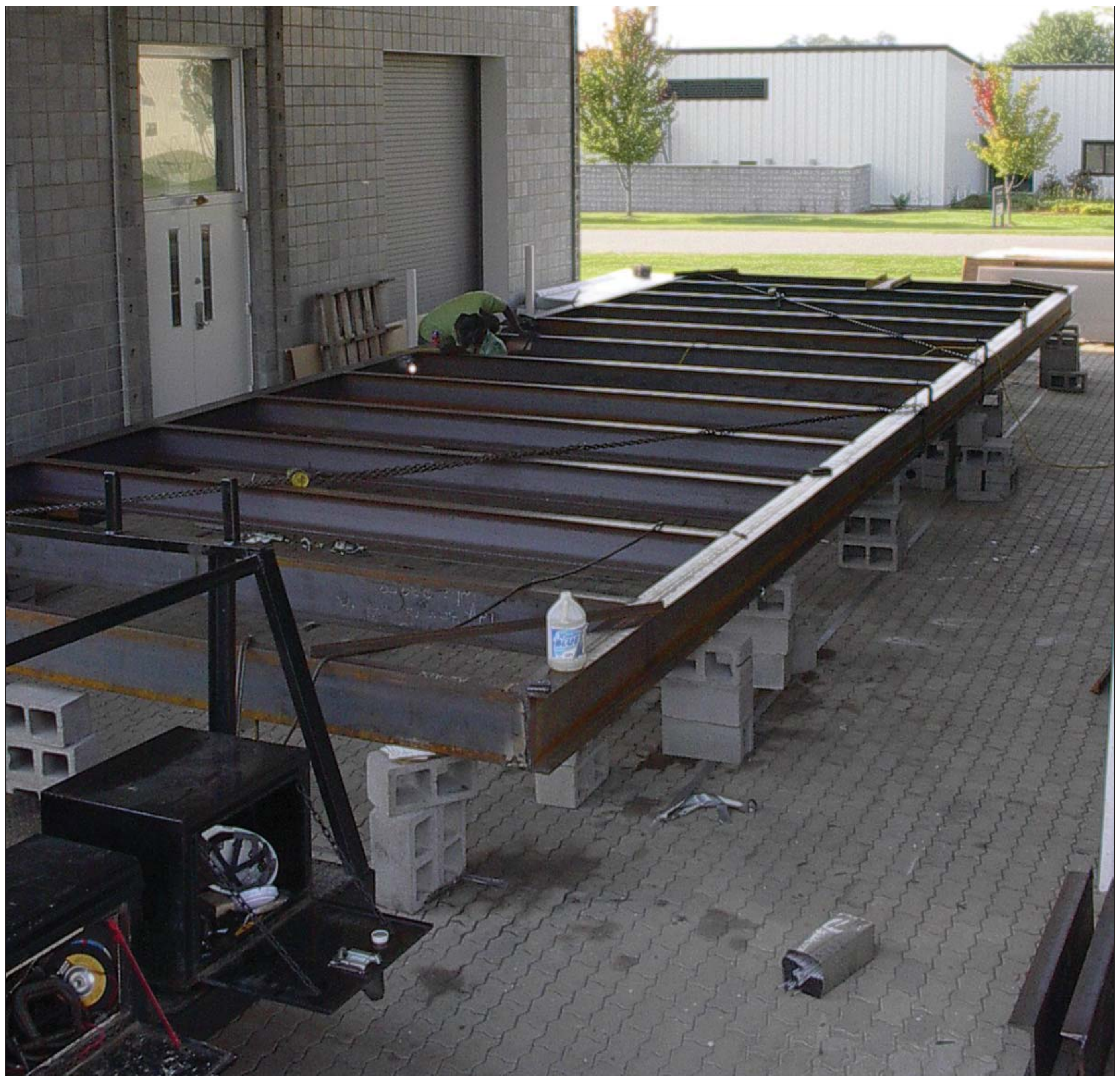


Assembling the truss

forests from logging. Additionally, the trees are harvested by cutting them and leaving a stump, which then will grow back into a mature tree.

Radiant floor installation

Chassis construction



SIP Panels installed above chassis

Underside of Chassis

Interior of solar house and the Lyptus flooring

Prefabricated deck system inset into truss frame

House arriving on the National Mall in Washington D.C.

House arriving on the National Mall in Washington D.C.

Element Two THE CORES

Interior of house displaying the two cores

The idea of served and servant spaces by Louis Kahn is applied to the design layout of the solar house. Kahn describes the servant spaces as spaces that serve the main spaces or served spaces, such as a closet in a bedroom or the A/C closet in a house. A house that is only 571 SF must be planned with maximum efficiency and optimal utilization of the space and systems, in order to exploit every square inch possible. The house combines all the servant spaces into two cores, the north core and the central core, which define the spaces and their functions.

The central core separates the open floor plan into two rooms, the private space and the public space, or the bedroom from the living, dining, and kitchen areas. A spacious bathroom is located inside the central core, with a sink, toilet and large bathtub. Because the bathroom requires

The Central Core that houses the bathroom the most privacy, it does not contain any windows directly to the exterior. The bathroom has a glass ceiling that is located below the main ceiling of the house and clerestory. This allows a considerable amount of daylight into this central and enclosed space, while maintaining maximum privacy. Additionally, the transparent ceiling makes this small space seem larger and affords a continuity of the dynamic quality that the main ceiling creates.

Located in the central core are two exterior vents that allow air to travel into the house when the exhaust fan systems in the clerestory are activated. Since the central core is located at the center of the house, placing these vents low to the ground provides cross ventilation throughout the house.

The two cores play an important structural role in the house. The house has ten steel columns that support the roof, five along the north side and five along the south. The northern core is attached to all five columns along the north side of the house, which provides a stiff shear wall; however, the southern five columns are freestanding in the main spaces and are more susceptible to the lateral loads. Essentially, the central core is a wooden box and can resist lateral loads. The steel C-channel, or moment resistance frame, that is connected to all the columns and runs around the entire house at the top of the walls and below the clerestory, is securely attached to the central core and north core that provide rigid lateral stability.

The north core runs along the northern side of the house, 48 feet long, 32 inches wide, and over 8 feet tall. This core houses most of the storage spaces, mechanical systems, appliances, and more. Having all these systems in a core that runs along the entire house is deliberate. For the mechanical systems, the core provides efficiency because of the close proximities, such as

The bathroom located inside the Central Core

the air conditioning and the air vents, the appliances and the water tanks, and the electrical closet and the appliances. Furthermore, the core has a strong relationship to the main spaces. For example, the kitchen that is located in the core is directly across from the dining space, the television defines the living area, the storage closets are located in the bedroom and the water tanks and heat pump system is located across from the bathroom.

Having the core located along the north side of the house creates an advantage, where the core acts as a buffer wall that protects the interior environment of the house from the cold winter winds from the north. The core is constructed of structural insulated panels, or SIPs, which provide both structural rigidity and excellent insulation. The interior of the core is made up of custom cabinetry made with recycled straw oriented strand board. The cabinetry is laminated with dark grey Formica that provides a sleek and clean appearance while protecting the wood cabinetry from water damage.

In the center of the core is the kitchen area, which has the counter workspace, kitchen sink, microwave, convection oven, stovetop, dishwasher, refrigerator, and cabinets. The kitchen has a large beautiful blue counter that is flush against a large horizontal window as its back splash, which allows plenty of natural light for task oriented jobs in the kitchen, reducing the need for electric light.

The main purpose of both cores is to conceal all the functions and spaces within the form. Most of the storage spaces are designed so that the wood panels can be pulled out for access and pushed in to conceal them. The television is inset into the wall across from the gathering space. The kitchen, located directly across from the dining space, is integrated into the core.

The bedroom

The connection points of the North Core to the C-Channel

The Kitchen in the North Core

SIP panels as the main structure of the North Core

The water tank, heat pump, radiant floor hub are all located directly across from the bathroom core for highest efficiency and shortest piping distances. Built in storage closets are located across from the bedroom including a washer/dryer.

Along the top of the core runs the duct work for the air conditioning system, where there are three vents for each main space. This allows for the cool air to fall from above and down to the floor in the summers. The vents are concealed in the core and the air is discharged within a reveal.

Part of the north core but accessible only from outside is the electrical room, which houses all the inverters, batteries, and computers that are needed for acquiring, storing, and distributing the energy from the photovoltaic arrays. The layout of these systems in the electrical room was designed taking into careful consideration its function as an exhibition to be understood by the general public. One additional piece that is integrated into the core's exterior is a sponsor's wall which is made up of a sheet of glass that is inset into the core at the front entrance. This glass consists of the names of the individuals and companies that generously donated money, materials, and/or labor to make the dream of this house come true.

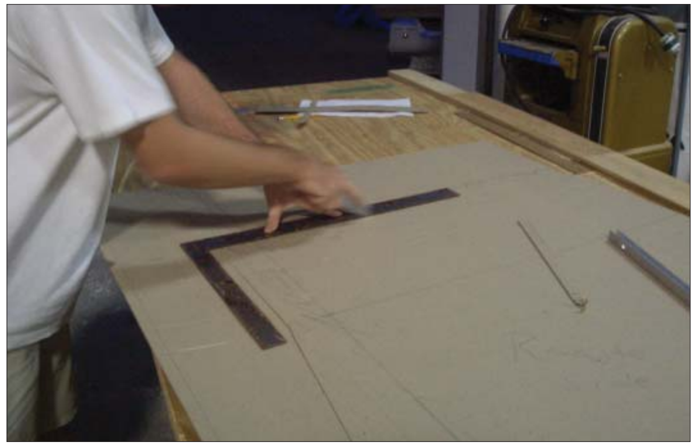
Core details In order to have a clean monolithic element made up of many pieces, each piece had to be carefully designed and constructed so that the storage doors and panels would be flush and the hardware would be hidden.

Storage spaces concealed in the North Core

Closet located in the Bedroom

Engineers and Architects During the competition, as one of the Virginia Tech students described the electrical closet with a strong emphasis of the graphical layout of the electrical components to the architectural jury, the juror was astonished to learn that this student was not an architecture student, but was actually an engineering student. Typically, engineering students would not care too much about the graphical layout of the electrical room. Because of the importance in the idea of integrating the engineering systems with the architecture, it was important to bring this idea to the knowledge of the students within the entire team. The architecture students learned from the engineering students and vice-versa, which developed an interest in each other's discipline. Furthermore, following this competition, one of the key structural engineers on the project enrolled in the masters of architecture program after developing a passion and an understanding for design.

Electrical Room on the exterior of the North Core



Creating templates of panels

Constructing full scale mock-ups to create complex pieces

The exterior of the north core is finished with a system of Alucobond panels, which are made up of two thin layers of aluminum that sandwich a plastic polyethylene core. Reducing the amount of high-embodied energy material such as aluminum, and with a longer lasting life cycle, these panels constitute an excellent alternative to other traditional cladding systems. This material comes in large sheets and is cut, routed and bent to custom forms, which allows excellent custom work to create the highest quality details that the design demands.

Finally, the front elevation has a photovoltaic array with six panels in the vertical position. This design meets three objectives: First, it brings a relationship of the interior space layout to the exterior by locating this array directly in front of the central core which divides the elevation into two. Second, it provides additional energy in the winter months when the sun is much lower. And third, it provides a direct interaction between the public and the photovoltaic array, where the public can see and touch the array while it is producing energy which greatly benefits the learning experience of the exhibition.

The Cladding System One of the most tedious tasks during the construction of the house was the fabrication of each Alucobond panel used for the core and the roof. There was a limited supply of donated material and mistakes could not be made. Every cut had to be measured three times before a cut was made. In order to assure maximum quality control, this process needed the full attention of two people at all times. Each piece was first cut to its correct size, and then clamped to a flat working table. Then lines were drawn at the location of each desired fold. A jig was constructed to be used as a guide for the router, which was routed to 1/10" thick, only millimeters from being cut completely through. After removing the corner pieces, the edges were folded at 90 degrees. Then pre cut aluminum angles about 6-inches long were clamped to the tabs of the panels about 12-inches apart. Once clamped three holes were drilled through both the panel and angle, where the holes were then riveted to attach the angle to the panel. The panel was then put in place and screwed to the wall or roof.

South Wall PV Array

Custom-making cladding panels

Cladding panels installed

View from North East of the house

Element THREE THE TRANSLUCENT WALLS

LED lighting system illuminated during construction

The idea of a volume of light drove the development of a truly sophisticated and innovative wall system, which was carefully studied and tested. Many factors were taken under consideration to form this system, such as translucency, material, light quality, air infiltration, temperature transfers, and control of light, privacy, and ventilation. The main focus of the design of the wall system is the translucency and thermal resistance characteristics as well as its tunability qualities that maximize its thermal resistance and use.

The wall is designed as a double skin envelope system made up of two layers of thin walls with airspace between. The two walls are made up of polycarbonate Lexan panels over 1.5 inches thick filled with aerogel, which provides a minimum of an R-8 thermal resistance rating for each panel. Aerogel is the lightest and least dense solid material in the world. It is made up of extremely small particles of silicon dioxide that are interconnected which is made by removing all liquid from silica gel, leaving its molecular structure intact. The most attractive qualities of aerogel are its translucency, its ability to resist temperatures 39 times higher than the best fiberglass insulation, and its extremely high resistance to sound transmission. Since the polycarbonate panels alone have very little thermal resistive quality, the hundreds of extruded honeycomb shaped cells in each panel are filled with aerogel. The two layers of filled polycarbonate panels create a 16 R-value wall system.

However, the wall system is a double envelope skin and has a 6-inch airspace between, which creates a total thermal resistance rating of R-22. This exceeds typical residential six-inch wall batt fiberglass insulation with a rating of R-19.

The translucency of these walls caused a number of issues that had to be addressed and the one-word answer to all these issues was tunability. For one, the fact that this system would accumulate an extreme amount of heat in the direct sunlight was problematic for the summer months while advantageous in the winter months. To resolve this, the wall system incorporates an adjustable ventilation system that is able to open during the summer months and close during the winter. This allows the hot air to escape and create airflow through the wall cavity in hot weather, and to contain the hot air in the cold weather, which maximizes the R-value of the wall. This ventilation system is opened and closed by motors that can be controlled by the occupant, or computer system, for ease of controllability. Other issues to resolve were privacy and light quantity. The answer is a motorized shading system located within the 6-inch airspace that can dramatically reduce the amount of light transmitted through the walls, thus providing extra privacy. Furthermore, the lowered black shading can act as an additional heat absorber during the winter months.

The LED light fixtures located at the bottom of and within the walls constitute another tunable element of the wall system. These lights allow the walls to become a light fixture for both the exterior and interior spaces. The highly efficient LED lights have the ability to be set to 16 million different colors and intensities. They provide ultimate controllability on the psychological affects produced by the color of the walls in a space. Last but not least, the LED lights wash the walls with color, thus reducing the need for painting.

Polycabonate panels

Ventilation system along the top of the wall

Aerogel

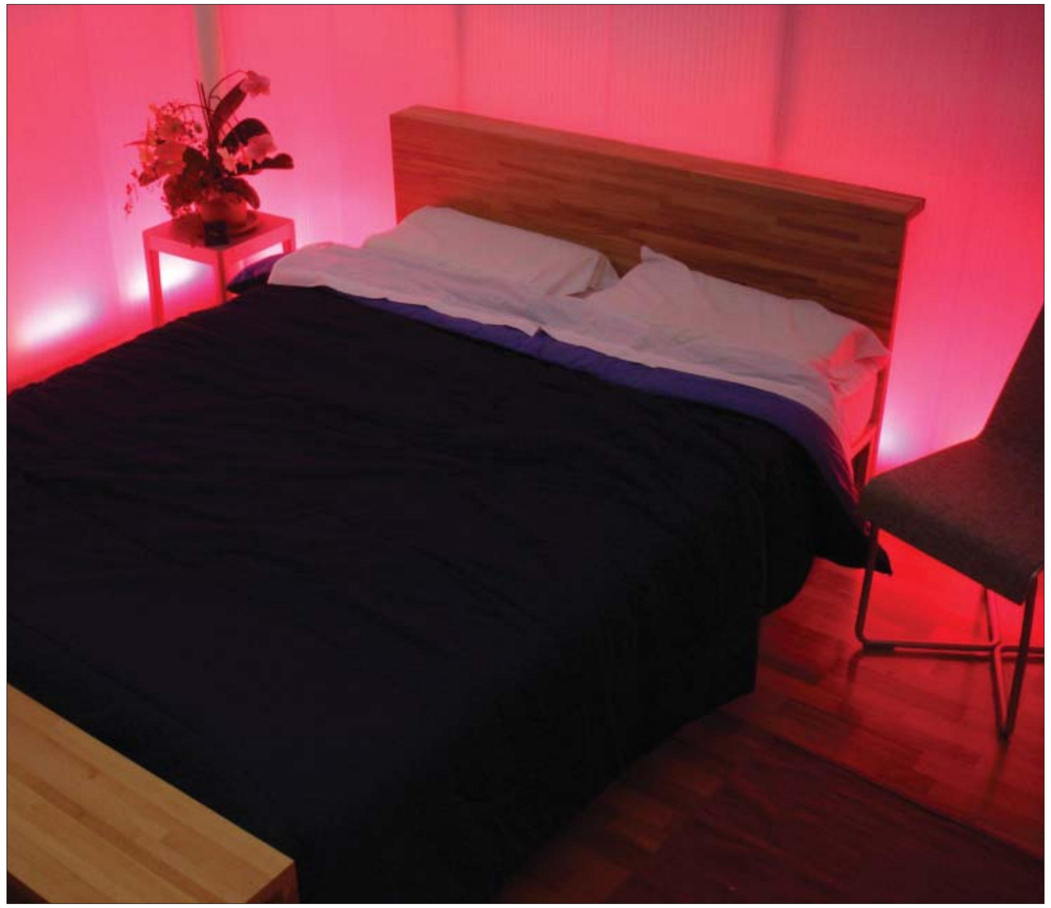
Interior space illuminated by the sun

Shading device partially closed

House Illuminated by the LED lights on the National Mall

House illuminated by the house lights

Wall system in the daytime



Using the LED lights to create room colors

The roof at night used with permission of Stefano Paltera / DOE Solar Decathlon 2005

Element FOUR THE FLOATING ROOF

THE ROOF, THE CEILING, THE COLUMNS, THE CLERESTORY

The element with the most important functions for a solar house is the roof because of the responsibility to contain the active system of the photovoltaic array, which transfers energy from the sun into electrical current. The Virginia Tech 2005 Solar House recognizes the importance of the roof by making it an iconic form that is both roof and ceiling and creates a dynamic spatial quality. Furthermore, the form of the roof gracefully gestures towards the sun while floating like a wing above the volume of light.

The roof's form was determined by its functional responsibilities, such as the need to provide an effective inclination towards the solar noon sun during the equinox, which maximizes the yearly absorption of solar energy for the photovoltaic array. The roof has an array of 36 Sun Power panels that are designed to be adjustable for different times of the year to capture more energy if needed.

The inverted shape of the roof is important for the passive solar strategies such as allowing for the roof to collect rain water for reuse, creating overhangs that shade in the summer months while maintaining the openness and views from within the house, and to conceal the photovoltaic array from view at the front.

The rainwater that the roof collects is directed to scuppers located at each end of the roof and then falls through a metal grate that is flush in the deck and into a cistern located under-

The Wetland water filtration system

neath. The water is then pumped into planters that consist of wetland plants where the water slowly spills over from planter to planter while being naturally purified by the roots of the plants. After several days, the water reaches the last planter and is clean and ready for reuse.

Since the roof is such an important element for the Solar House, the purity of its shape is strictly maintained. As for any roof that shelters a house from the elements, it is constructed out of many pieces and systems that need to work concurrently to make it functional. The solar house carefully integrates each piece and system into the roof's form to maintain the

Constructing the roof beams

Constructing the roof section

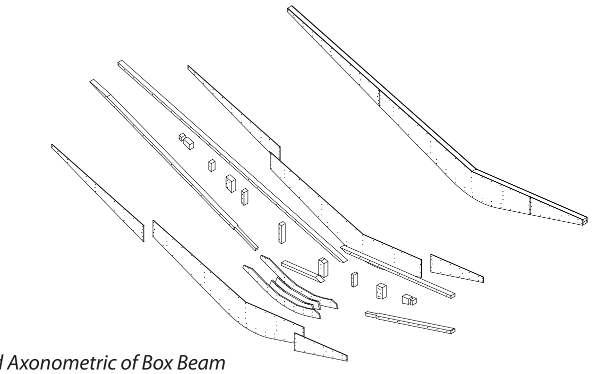
The dynamic space created by the Roof

The roof beam jig used to make precise duplicates of the beam and held the beam together while the glue dried

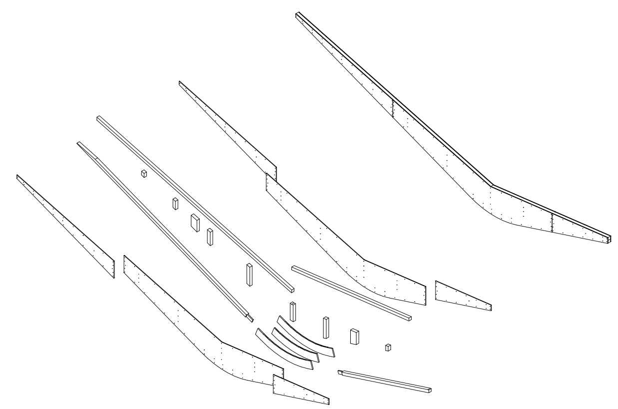
Preparing the roof section to apply the skin

Lifting one of the roof sections into place sleek, clean look that maximizes its importance and grace. Additionally, in order to maintain the purity of the roof's form, there are intentionally no lights in the roof/ceiling—the ceiling lights are located in a light shelf along the bottom of the clerestory and illuminate the underside of the roof to create an even amount of light to be reflected into the space.

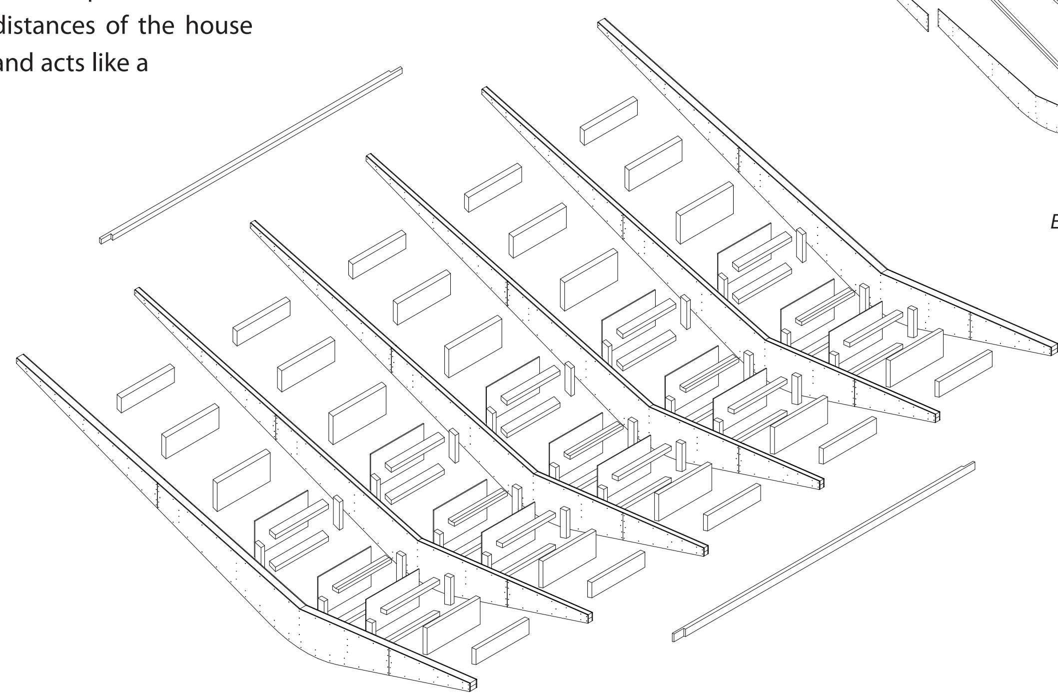
The structure of the roof was tested many times before the finalization of the design. How a roof constructed of wood and weighing over 4,000 pounds was going to span between columns over 10 feet apart in both directions was going to test the ingenuity of the design team. Based on the shape of the roof and the structural strengths of its inverted form, we designed the structure as a stress skin folded plate system. The stress skin structure is developed for the spans between the short distances of the house and acts like a



Exploded Axonometric of Box Beam



Exploded Axonometric of Box Truss



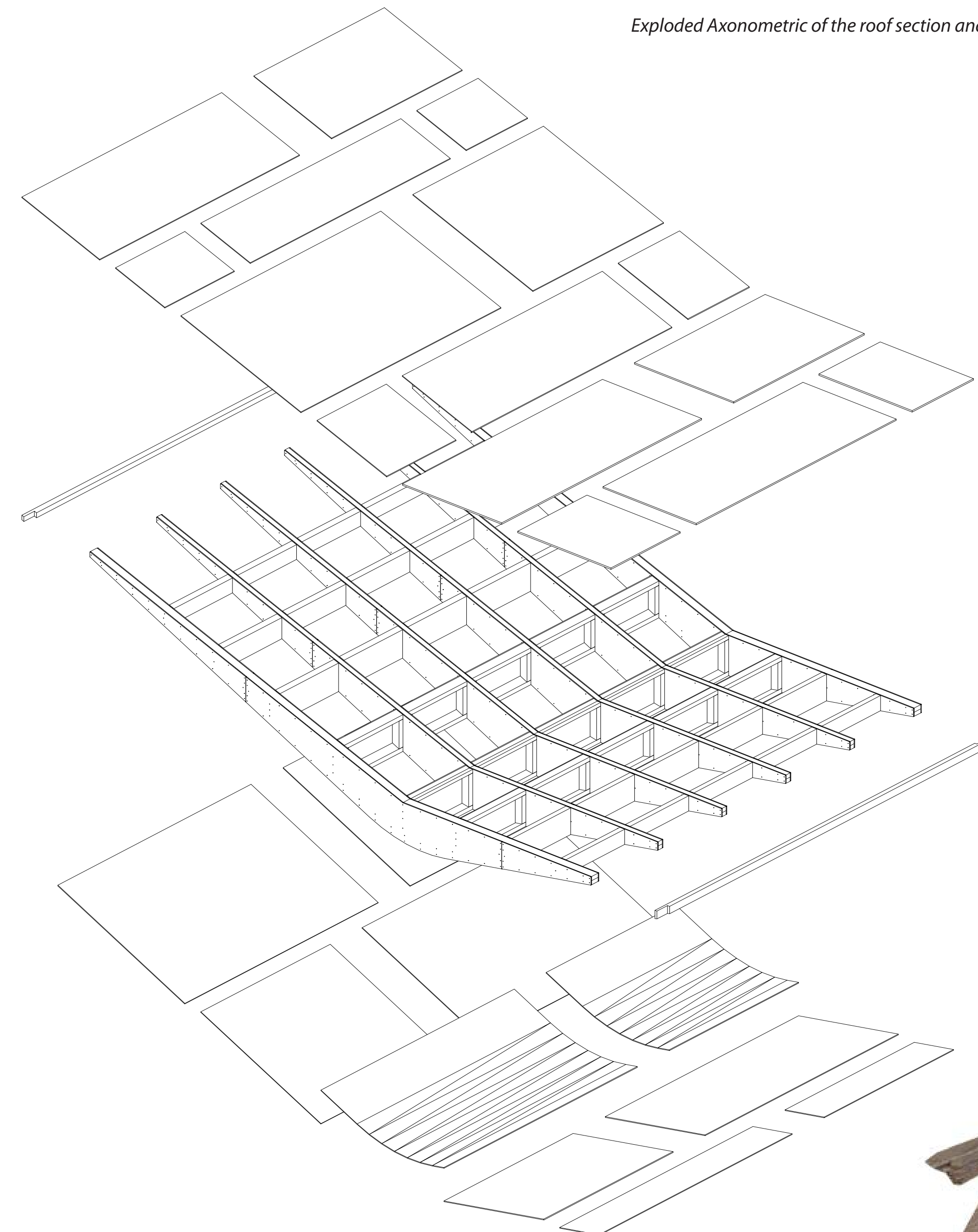
Exploded Axonometric of Roof Section

Planing the wood to exact dimensions

Cutting pieces for the roof

Notching wood pieces

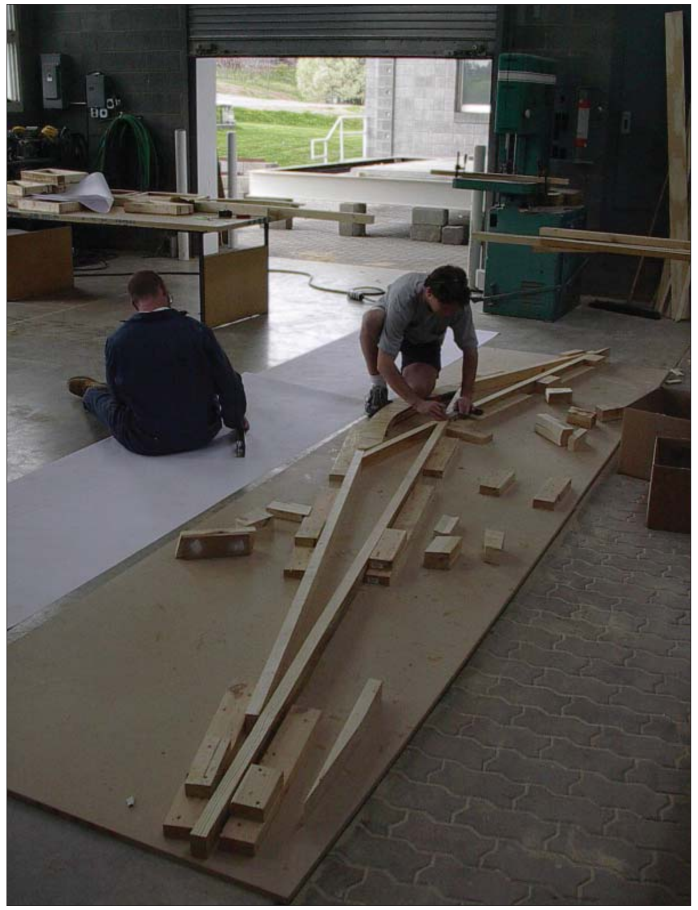
Exploded Axonometric of the roof section and stretched skin



Routing pieces for the box beams

Using a template to duplicate exact pieces

Placing the pieces into the roof jig



Pieces drying in roof jig

Detail connection of wood pieces in the box beams

Interior of the box beam

Structural Testing Many full-scale roof mock-ups were constructed, in order to study the best type of construction and its structural strengths. We consulted the engineering department for structural design assistance with the wood roof. Most of the engineers were more comfortable with steel or concrete design, but wood was a bit uncommon in what they usually calculate. A few of the engineers came and studied our first full scale mock-up and saw that a stressed skin type structure was the primary structure of the building and located with us the most critical areas. We constructed a full-scale piece for testing and calculated that it would need to support over 1,000 pounds due to dead and live loads including safety factors. Also the roof was only able to deflect a maximum of a half an inch until it was considered a failure. Most of the engineers bet that for sure our design would fail easily. We placed the full load of weight and the roof only deflected an eighth of an inch. We decided to place as much weight we could find and double the amount and still the roof only deflected a quarter of an inch. We decided to leave the load on the beams over night to see how the structure would perform over a 24-hour period and still it was only deflecting a 1/4 of an inch. The engineers were amazed and lost there bet since our roofs structure passed the test and was ready for construction.

Connection of two pieces

Meeting with engineers discussing the roof design

Preparing to test the beam

Loading the beam for testing

Installing the expanding foam insulation

Installing the Rigid Insulation

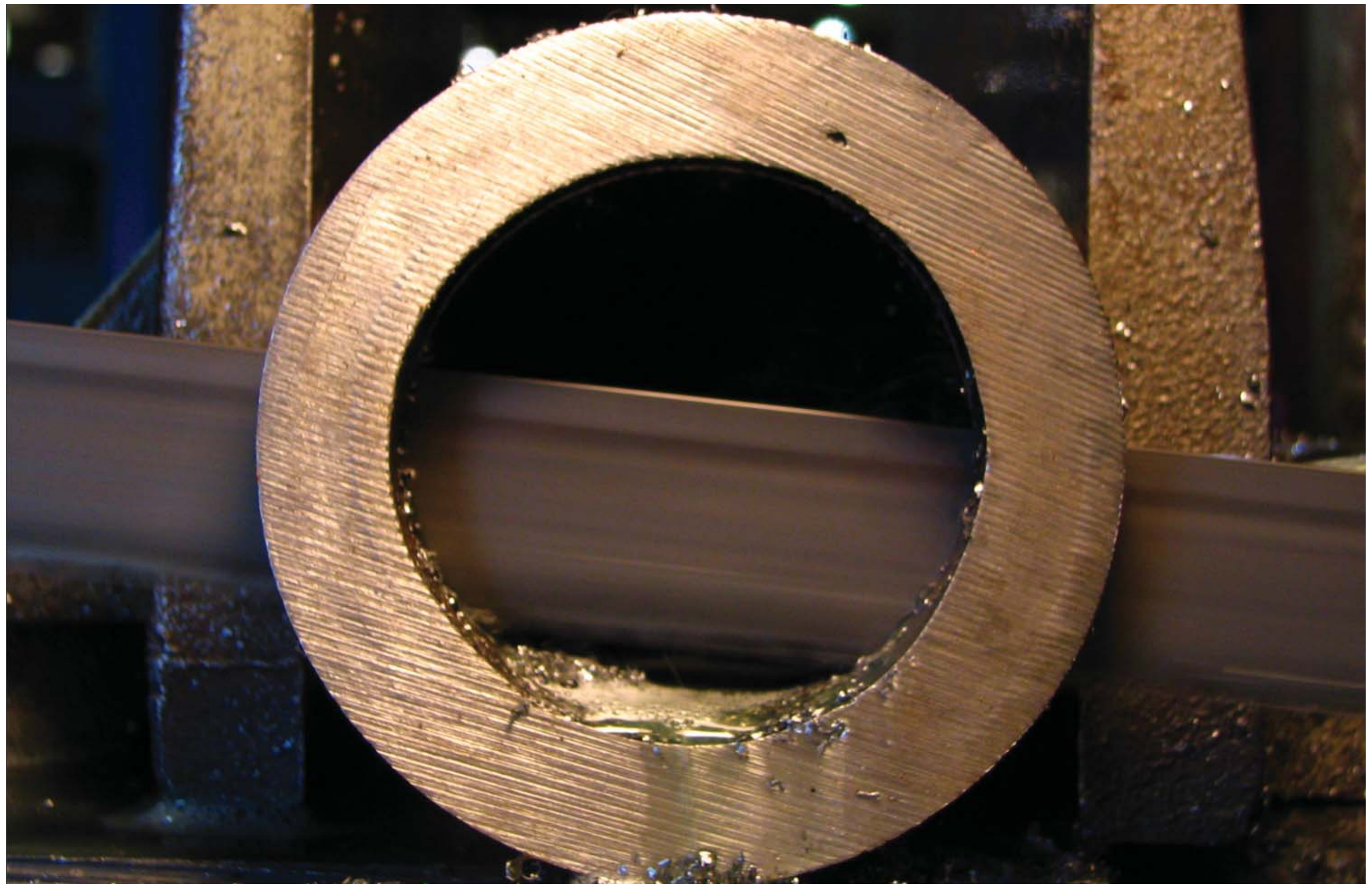
Installing the waterproof membrane

Installing the cladding system to the roof

hammock stretched from column to column, while the fold of the roof creates a folded plate to span the roof in the long direction.

The roof is made up of five prefabricated panels constructed on the ground and then lifted into place. Each panel weighs over 1,000 pounds and must resist additional live and snow loads. The most critical structural element in the roof design is the ¼-inch plywood sheathing along the bend of the ceiling. The plywood is attached to wooden box beams and box trusses that act as ribs that span in the short direction of the house. These box beams and trusses were constructed using a wooden jig that maintained exact dimensions from one to the next. The box trusses provided additional strength by creating a triangular frame and are located at the columns while the box beams are located in between the columns. Wooden sheathed frames that provide cross bracing as well as equal spacing connect the beams to each other. Once all the beams and trusses are connected, the roof is then sheathed on the underside using the ¼-inch plywood. Once sheathed, it is then flipped right side up and lifted into place. Each section is bolted to the columns and to each other. Once the five sections are all in place, the cavities are filled with expanding polyurethane insulation foam, which provides excellent insulation as well as added rigidity. Last is a thick layer of plywood that is sheathed across the top for added structural strength in the long direction.

Cutting the steel column



Steel column ground to 45 degrees for welding

Constructing center point to column base

The underside of the exterior portions of the roof is Alucobond cladding that creates a durable and sleek finish. The underside of the interior portion of the roof is covered with a stretched fabric that creates a warm, soft texture and reflects the light evenly throughout the space. The top of the roof is insulated with rigid insulation and protected by a white polyethylene PVC membrane that is welded together to eliminate all seams and reduce leakage. The edge detail of the roof is a typical coping detail, which is designed to be flush with the Alucobond panels in order to maintain the purity of the form.

The roof floating over the space provides an exceptional spatial experience as well as the impression that the space is much larger than its 571 square feet. The choice of columns, as opposed to walls, to support the roof and clerestory contributed to creating the perception of a floating roof. The columns have been an interesting component of the design from the beginning.

The columns were initially drawn in the plans as small circles without understanding the reality that these were actually ten columns of steel that weigh over 250-pounds each and required four people to put each one in place. The columns were

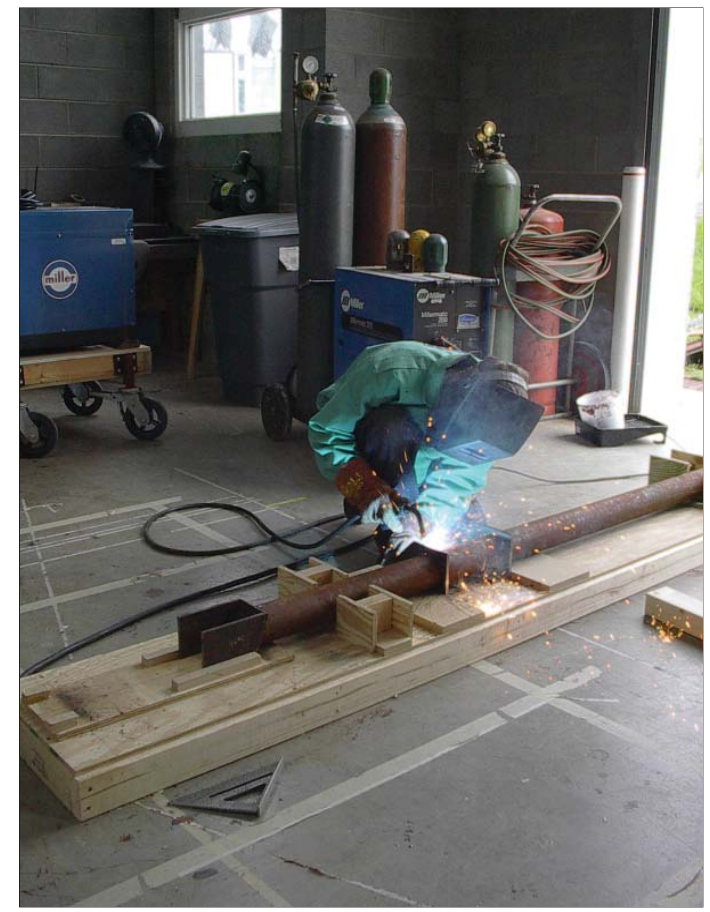
Column bolted to Chassis

Centering the column's base plate
Deciding how to place a flat piece of steel exactly center to a column, when the base of the column has been ground at a 45 degree angle, was a challenging task. I came up with a solution by cutting flat stock steel squares with dimensions that exactly match the interior diameter of the column. We were then able to locate the center of the squares and the base plate and drill a center hole in both. Then we attached the square to the base plate using standard nut and bolt. We were now able to insert the base plate into the column locating it precisely centered. The base plate was then welded to the column and then the bolt was cut off leaving the steel square forever inside the column.

first cut by an acetylene torch and then precisely cut by a drop saw. Both ends had to be ground down at a 45-degree angle to prepare for the fillet welds. A jig had to be constructed to set the base plates, the top plates, and the collar connection plates in order to maintain quality control during welding. The columns were then bolted to the main steel chassis with a brake pad between that created a thermal break. Each column is connected to a steel collar beam C-channel that wraps the entire house. The C-channel is designed to support the clere-story glass, provide a secure connection to the top of the walls, a continuous connection for the top of the steel transporta-tion truss system, and lateral stability for the entire house.

Grinding the column

Column is in Jig ready for welding



Column being welded together

Column being lifted into place

Column being attached to C-Channel

THE DETAILS
THE STUDY OF SELECTED DETAILS

The entrance

With an understanding of the overall concept, the various issues that had to be addressed by the team in the design and building process, and the particular features of the main elements of the house, it is possible to appreciate the significance of each of the details selected to illustrate this study.

DETAIL 1

THE ROOF EDGE : INTEGRATION OF THE COPING SYSTEM

The roof edge is a critical piece in all roof designs. The concept of our design is that of a floating, wing-like roof with a monolithic appearance, which strengthens its presence as an element as well as adds elegance and grace. The edge of the roof requires a coping system that protects the roof from water infiltration. Normally, this coping system would protrude out from the cladding system of a building, which would be problematic for the concept of a monolithic, seamless roof. To remain faithful to the design, the edge coping and paneling systems must be integrated in a seamless transition of materials.

To this end, the Alucobond panels of the cladding system were designed with the shape needed to cover the recess created by the coping system. Thus both systems can be placed flush with each other, creating a seamless transition that contributes to the integrity of the architectural concept. In conclusion, this detail achieves two things: it integrates a standard system into the roof's shape and at the same time enhances the monolithic perception of the roof element.

(1) 3/4" PLY-WOOD - STRESSED SKIN

(2) 1/"4" PLY-WOOD - STRESS SKIN

(3) CONNECTION SCREW

(4) ALUCOBOND PANEL

(5) EXPANDED FOAM INSULATION

(6) RIGID INSULATION

(7) ALUMINUM ANGLE

(8) COPING SYSTEM

(9) COPING FASCIA

(10) ROOF MEMBRANE

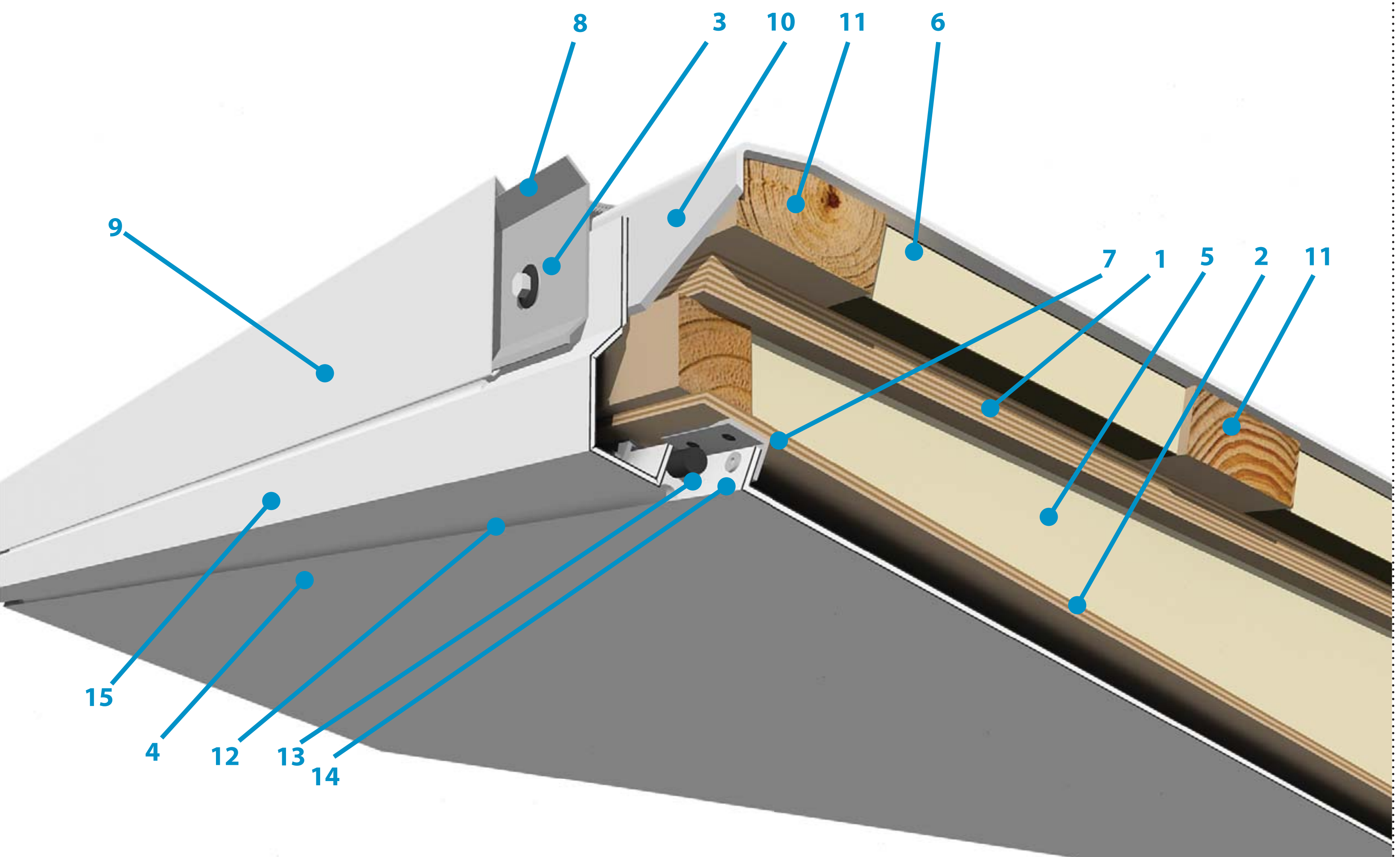
(11) WOOD STUD

(12) WHITE CAULKING

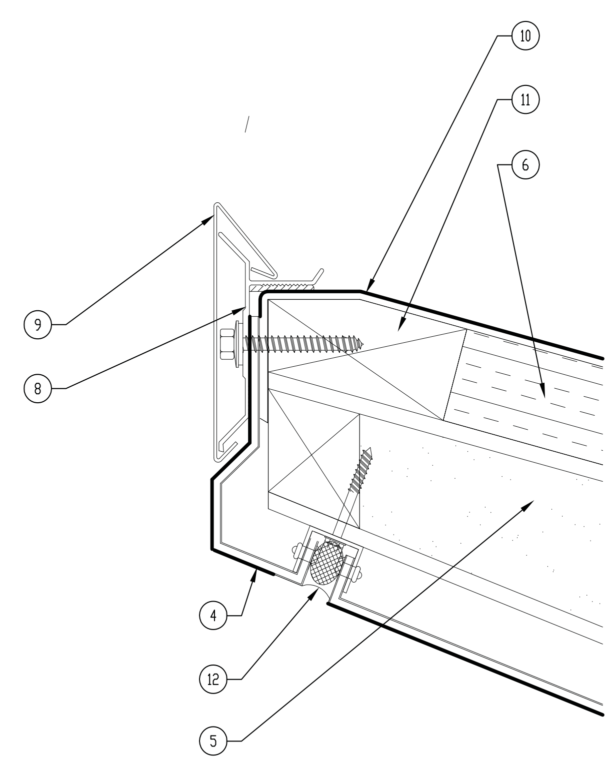
(13) BACKING MATERIAL

(14) RIVET

(15) ALUCOBOND DETAIL



The roof edge



Drawing of the edge detail

Render of what the standard detail of the coping system would look like

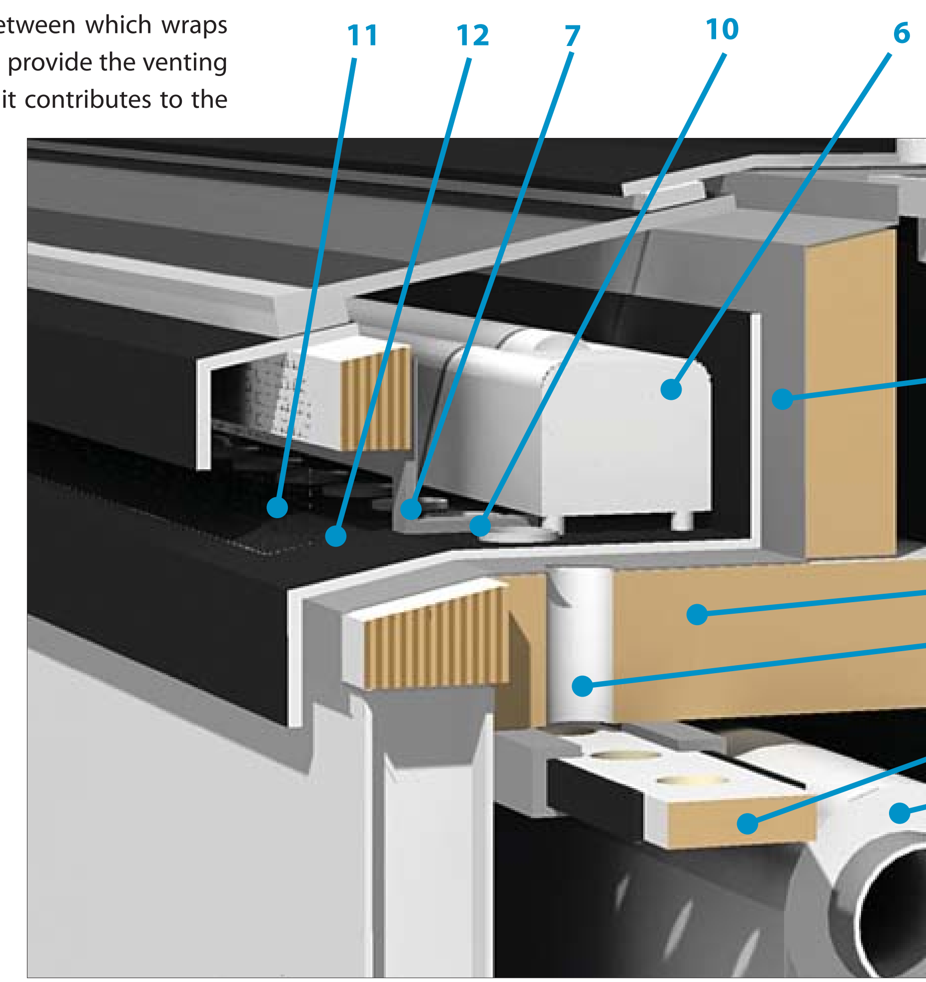
DETAIL 2

THE WALL CAP : A VISUAL DATUM LINE

The translucent box of the wall system is maintained with as little interruption in the façade as possible, which creates an elegant lightweight perception. The top of the wall is to have a datum line that defines the top of the volume and the clerestory. Everything between the datum line and the roof is to be open and have minimal obstructions. All of this contributes to the effect of a roof floating over a volume of light.

Behind the datum line at the top of the wall there is a complex system, or series of systems, in charge of a variety of functions: tunability to the wall system, including ventilation and a shading device; structural connectivity for the wall system, the truss system during transportation, and the clerestory windows; and the main indoor and outdoor lighting system. Typically, this would result in the top of the wall having a thick, heavy-looking band to contain all these systems within, which in this case would deteriorate the strength of the illuminating volume and the lightness and elegance of the architecture.

As a solution, the wall cap at the datum line is made of two aluminum pieces with an open slit in between which wraps around the house. The slit is necessary to provide the venting for the wall and light; at the same time, it contributes to the appearance of a thinner and lighter wall cap. The design and construction of the slit required a lot of thought and preparation. We took thin bent strips of Alucobond, aluminum sheets that are glued to thin strips of plywood, and attached the lower piece of plywood to the header along the wall. There is a small lip created by the Alucobond piece, which drops below and further out from the polycarbonate wall, which is necessary to create a drip edge. The second strip, above the slit, is connected with thin aluminum angles every 16 inches and attached to the wall header below. Water infiltration was a large concern in this area. The flashing had to be carefully planned especially when there are vent holes in the top of the wall. In order to protect these vent holes from condensation and pressure driven rain, small PVC piping was cut into rings and sealed at the perimeter of each hole so the water could not enter into the



(1) CLERESTORY ARGON FILLED GLASS

(2) STRUCTURAL CONNECTION FOR TRUSS SYSTEM DURING TRANSPORTATION

(3) PLEXIGLAS FOR EXTERIOR LIGHTING

(4) LINEAR ACTUATOR

(5) VENTILATION HOLES

(6) EXTERIOR LIGHTING

(7) ANGLE BRACKETS

(8) WALL HEADER

(9) FLASHING

(10) PVC LIP

(11) BUG SCREEN

(12) ALUCOBOND WALL CAP

(13) CONTINUOUS OPEN SLIT FOR VENTILATION

(14) AEROGEL FILLED POLYCARBONATE PANELS

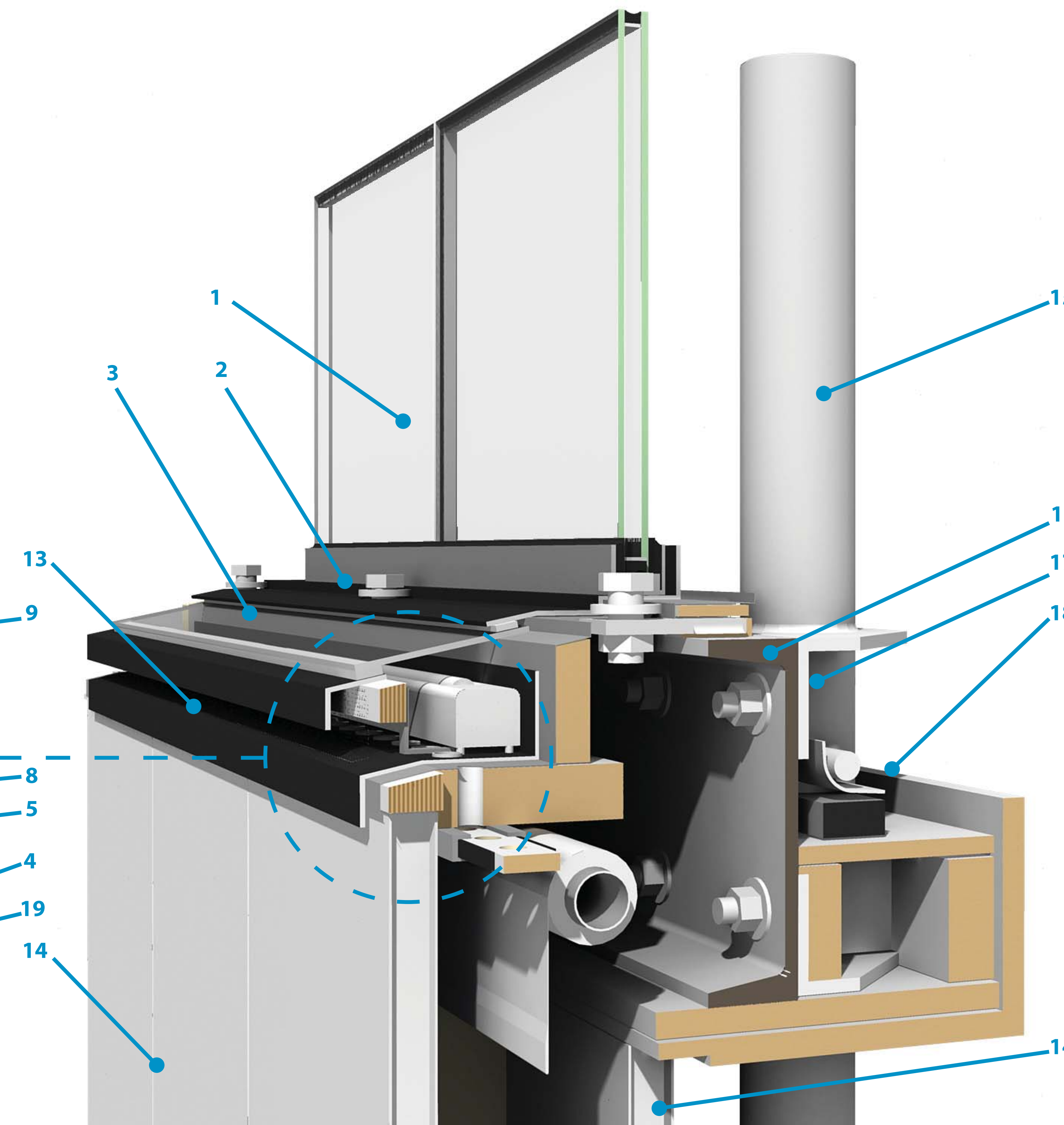
(15) STEEL COLUMN

(16) STEEL C-CHANNEL

(17) BRACKET CONNECTION

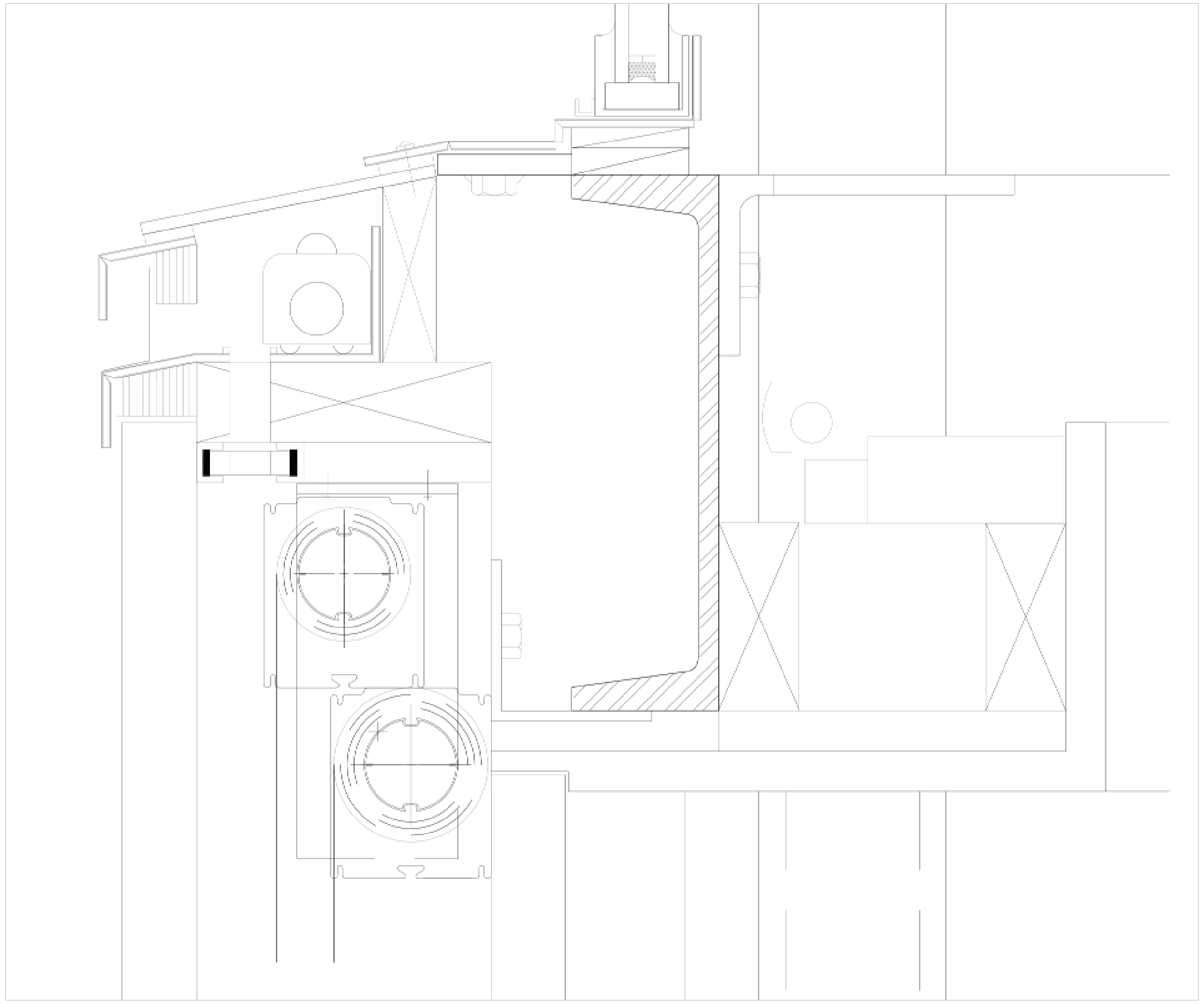
(18) LIGHT SHELF

(19) SHADING DEVICE



wall systems.

This detail successfully provides excellent water proofing and protection to the wall system, structural support during transportation to the wall and clerestory, and adequate ventilation, lighting, and shading to the wall and roof—all while contributing to the elegance and purity of the volume of light concept. One reservation with regard to this detail concerns the point at which the long pieces of Alucobond join: when heated in the sun the aluminum expands and causes the two pieces to compress together and then warp out. This portion of the detail should have been more thought out to avoid this situation.



Detail drawing of the wall cap

Ventilation system along the top of the wall

The elevation of the wall and the wall cap

DETAIL 3

THE NORTH WALL CLADDING : THE TOP END PANELS

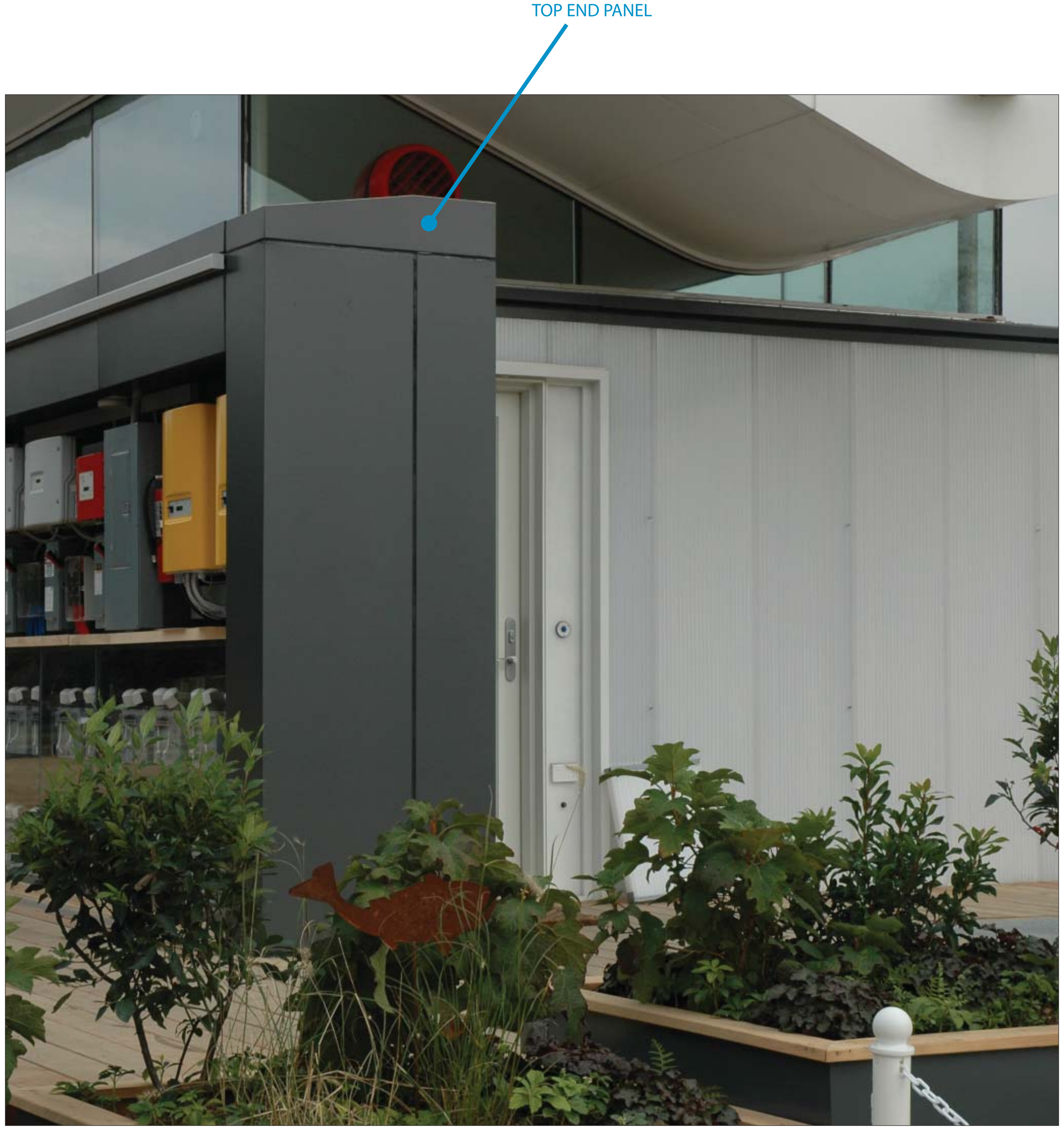
The northern core wall should give an appearance of heaviness to serve as a visual anchor and enhance the integrated appearance of the house. There are many cladding panels that make up the core wall. This cladding system protects the wall from the elements. There are expansion joints between panels to allow room for movement due to temperature change.

The decision on how a panel turns a corner as one piece is essential to the appearance of heaviness intended for the core wall element. It adds weight to the wall, as if the panels were made of solid blocks and the voids were carved out of the wall element. If the corners had typical construction details such as joints or additional corner pieces applied, then the appearance of heaviness would be lost and the effect of the element would weaken considerably.

The top end piece of the wall, visible on three sides, was the most difficult piece to make. It had to be designed with cardboard first in order to create a template. Once the template was created, then this could be transferred to the Alucobond aluminum material. The Alucobond aluminum material was then fabricated and fitted on the top end of the wall to add to the perception that the wall is made up of solid aluminum pieces.

The design decisions and successful application of this one panel greatly contributes to making the north core wall appear as a strong monolithic element that anchors the house and enhances its integrated quality.

Constructing a mock-up of the end piece



DETAIL 4

THE PIVOTING POINTS : THE STEEL TABS

In our design, two different systems are provided by what is actually a single element with a double function. The truss system, which provides structural strength during transportation, can double as the structural frames for the exterior platform deck that provides a base plane for the house to sit on. The detail must be simple and functional for the truss to be able to pivot. It must be sized accurately so that when the truss is down and being used as a deck it is flush with the top of the decking.

To this end, the detail is designed as vertical tabs welded to the main I-beams of the chassis. These tabs have a rotating pin connection, which allows the truss to be rotated. The truss must be shaped on the ends in order to clear the wall when being rotated. This detail succeeds by providing both the structural connection needed by the truss and allowing the pivoting of the truss to provide a base plane for the house.

(1) I-BEAM

(2) STRUCTURAL INSULATED PANEL

(3) FINISH FLOOR

(4) POLYCARBONATE PANEL

(5) WALL BASE SYSTEM

(6) PIVOTING JOINT

(7) MAIN I-BEAM - CHASSIS

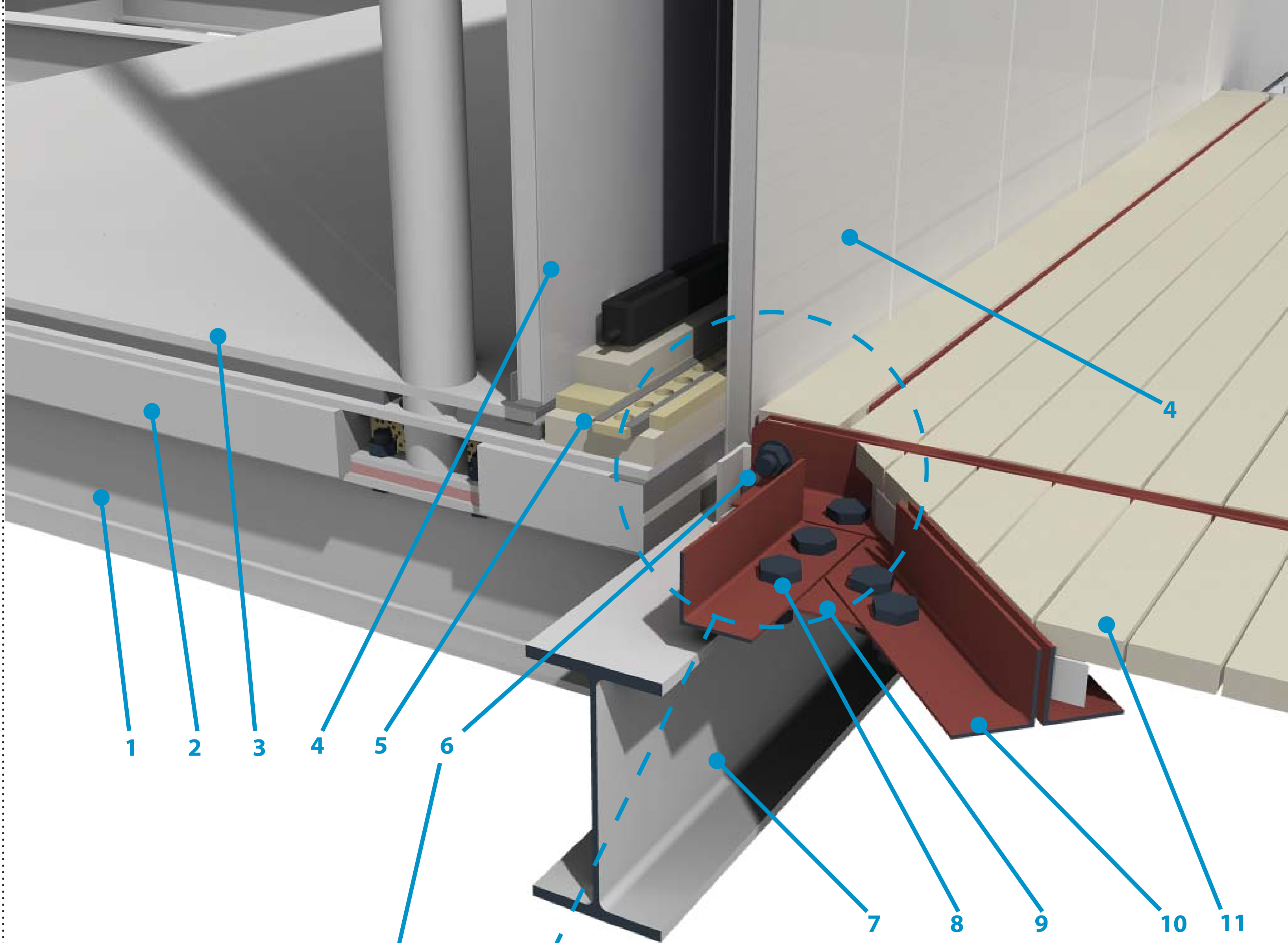
(8) 1-INCH BOLTS

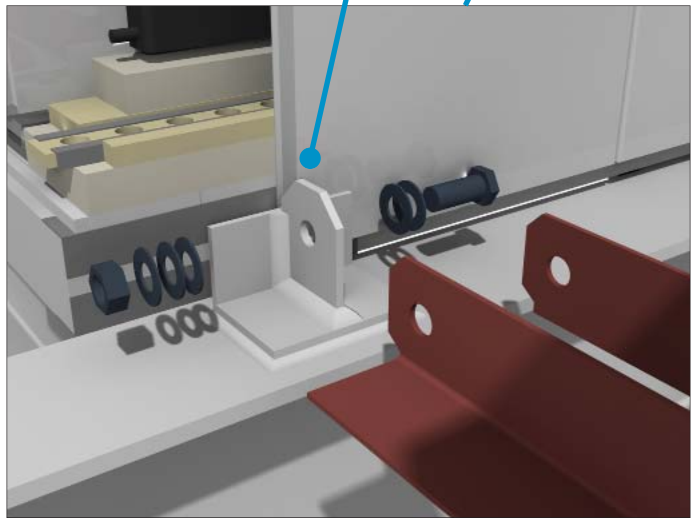
(9) GUSSET PLATE

(10) STEEL ANGLE TRUSS CHORD

(11) CEDAR DECKING

Design of the truss pivoting tab system with an actual one inch bolt used on the truss





Pivot Connection Detail

Pivot connection and gusset plate of the truss

THE CONCLUSION

Through the experience and the process of design and construction of the 2005 Virginia Tech Solar House, the importance of a well-designed detail in relationship to the overall architectural idea became evident. There is no question that the details had a direct impact on the overall idea of the house.

The roof edge, the wall cap, the top corner panel, and the pivoting steel tab—all these details support the notion that the details contain the architecture. Without the ingenuity and effort necessary to bring these pieces together, the overall architectural concept, and therefore the architecture, would have been lost. These details are representative of the many specific choices made to meet the various challenges that presented themselves without compromising the integrity of the central idea: a house that highlights and celebrates its solar aspects while at the same time integrating the engineering systems and architecture into a monolithic form.

The details contain the architecture of buildings: poor details make poor buildings and outstanding works of architecture are designed thoroughly with details that have an excellent relationship to the central idea.

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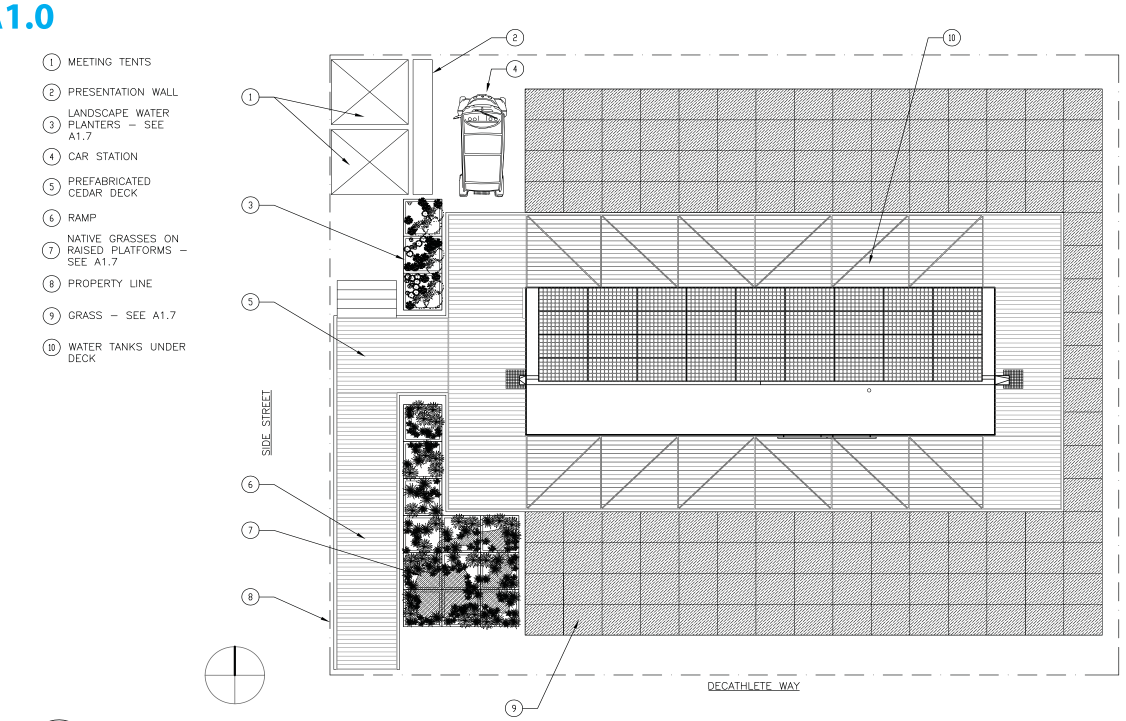
MECHANICAL

M1.0 FLOOR PLAN - HVAC
M2.0 FLOOR PLAN - RADIANT FLOOR HEATING SYSTEM
M3.0 MECHANICAL SECTIONS AND DETAILS
M4.0 MECHANICAL ROOM PIPING SCHEMATIC
M5.0 RADIANT FLOOR HEATING SYSTEM SCHEMATIC
M6.0 CONTROL SYSTEM SCHEMATIC

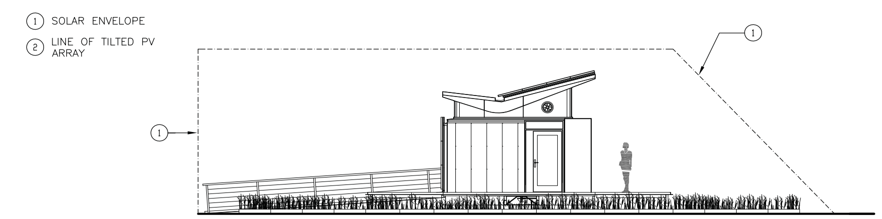
C1.0 CONSTRUCTION SCHEDULE

A0.1

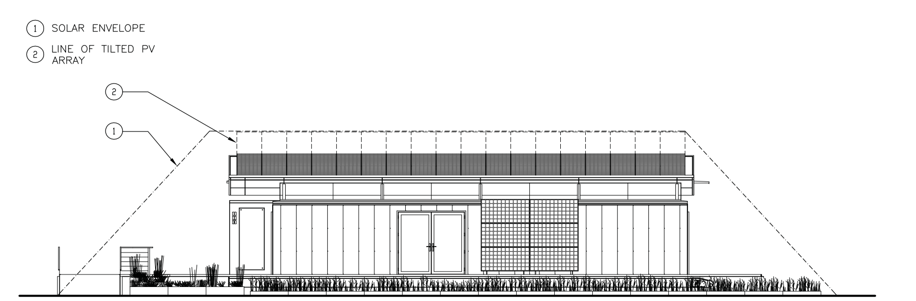
A1.0



A 1.0 SITE PLAN
SCALE: 1/8" = 1'-0"



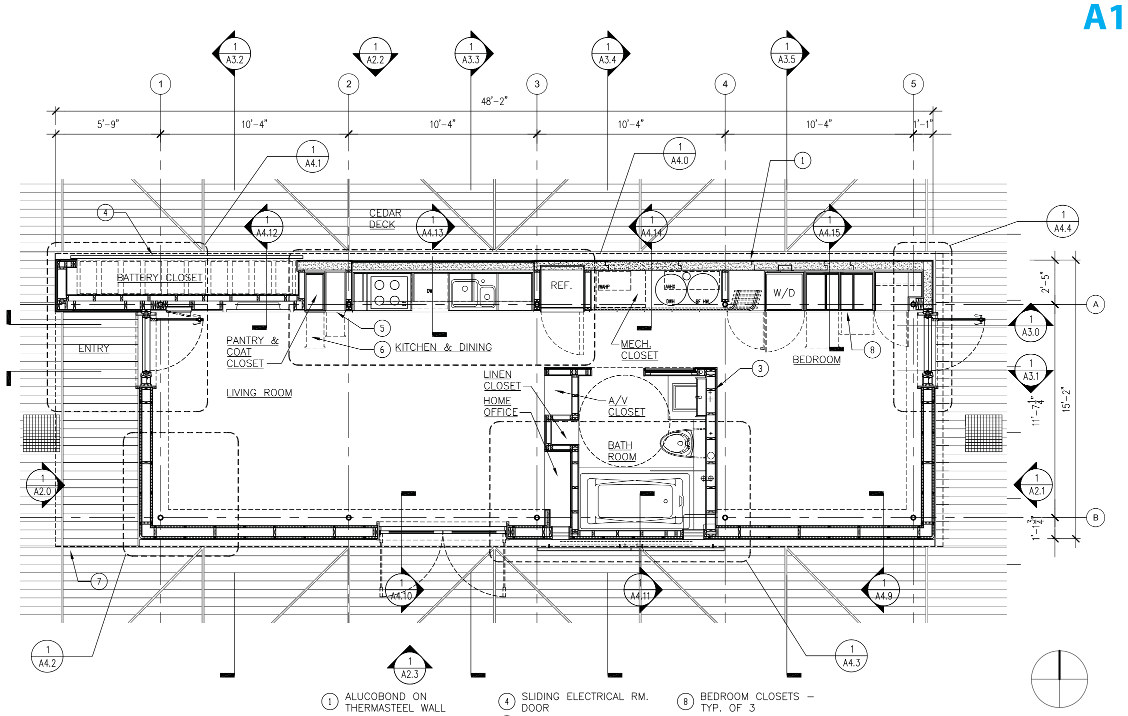
B 1.1 SITE ELEVATIONS
SCALE: 1/8" = 1'-0"



A 1.1 SITE ELEVATIONS
SCALE: 1/8" = 1'-0"

A1.1

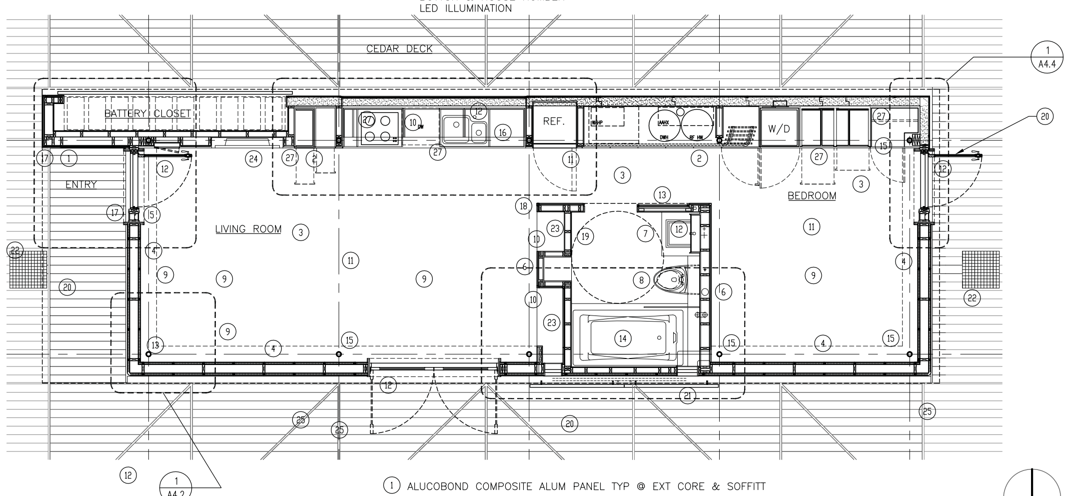
A1.2



1. ALUCOBOND ON THERMASTEEL WALL
2. POLYCARBONATE WALL SYSTEM
3. MAPLE PLYWD ON WD STUDS – TYP. OF EXT. BATH WALLS
4. SLIDING ELECTRICAL RM. DOOR
5. PULLOUT PANTRY
6. COAT CLOSET
7. LINE OF ROOF ABOVE
8. BEDROOM CLOSETS – TYP. OF 3

A 1.2 PLAN
SCALE: 1/4" = 1'-0"

6. MAPLE VENEERD PLYWOOD WALL
7. GLASS TILE RECYCLED ON FLOOR AND WALLS
8. LOW FLOW BATHROOM FIXTURES
9. FURNISHINGS CUSTOM OF IKEA PRONOMEN COUNTERTOP WOOD
10. P-LAM COUNTERTOPS – FORMICA "GRANITE"
11. WHITE STRETCHED FABRIC CLG BY MECHOSHADE
12. INSULATED GLASS DOORS & WINDOWS
13. ACID ETCHED SLIDING GLASS BATHROOM DOOR
14. KOHLER'S PURIST LINE OF LOW FLOW FIXTURES IN BATH & KITCHEN
15. PAINTED STEEL COLS BONE WHITE
16. ACID ETCHED GLASS KITCHEN CUPBOARD DOORS
17. SPORE INC/ DOORBELL BUTTON & HOUSE NUMBER LED ILLUMINATION
18. SPORE INC DOORBELL
19. TRANSPARENT POLYCARBONATE BATH CEILING
20. CEDAR DECKING
21. SUNPOWER SP200 BLK AESTHETIC SOLAR PANEL SOUTHWALL
22. ALUCOBOND SLUPPERS FOR GREYWATER COLLECTION
23. CNC ROUTED MDF PANELS DOWNLIT
24. LCD DISPLAY
25. EXPOSED STL EDGE OF TRUSS ANGLE BELOW DECK
26. MTL GRATE OVER CISTERN WATER COLLECTORS BELOW
27. CABINETRY OF STAINED WHEATBOARD MATERIAL BY CALIF CLOSETS

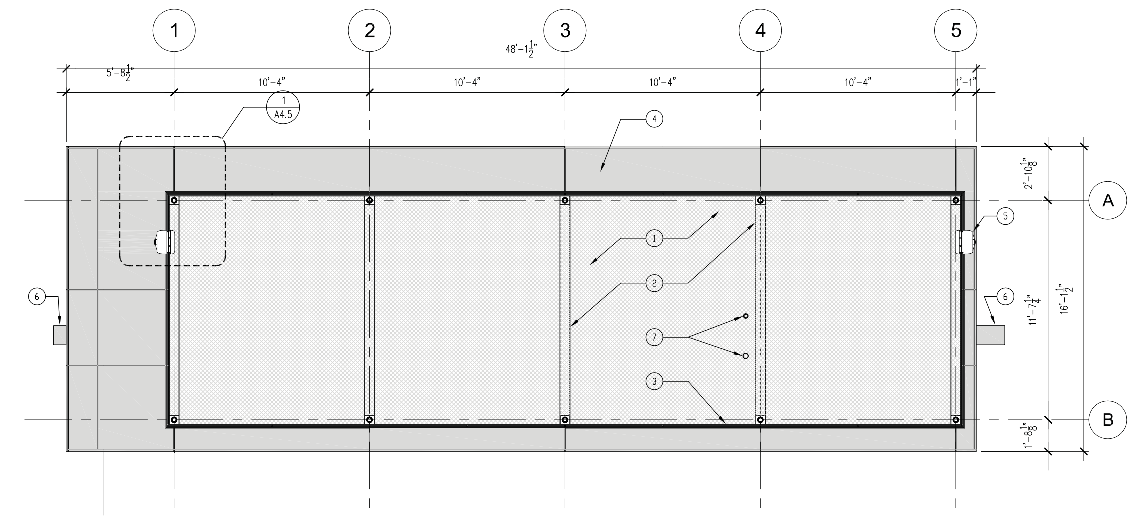


1. ALUCOBOND COMPOSITE ALUM PANEL TYP @ EXT CORE & SOFFIT
2. P-LAM DOOR FRONTS & PANELS, FORMICA "GRENADINE" TYP @ N INT CORE WALL
3. LYPTUS EUCALYPTUS ENGINEERED FLOATING FLOOR
4. TRANSLUCENT AEROGEL FILLED POLYCARBONATE PANEL WALL R22
5. "SHERCRYL" PAINTED DOOR FRAMES BONE WHITE

A 1.3 MATERIAL PLAN
SCALE: 1/4" = 1'-0"

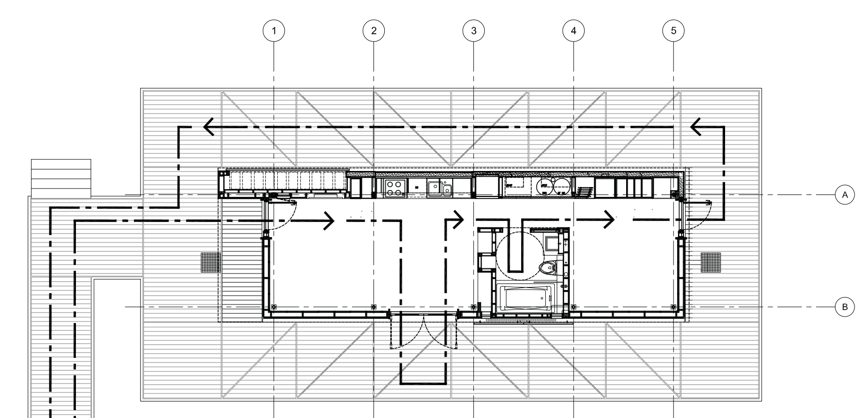
A1.3

A1.4



1. STRETCHED FABRIC CLG. "EUROVEIL"
2. PANEL SEAM
3. 1" CLERESTORY INSULATED GLASS
4. "ALUCOBOND" COMPOSITE MTL. PANEL
5. VENTILATOR FAN – TYP. OF 2
6. SCUPPER
7. ELECT. & PLUMBING CHASE

A 1.4 REFLECTED CEILING PLAN
SCALE: 1/4" = 1'-0"



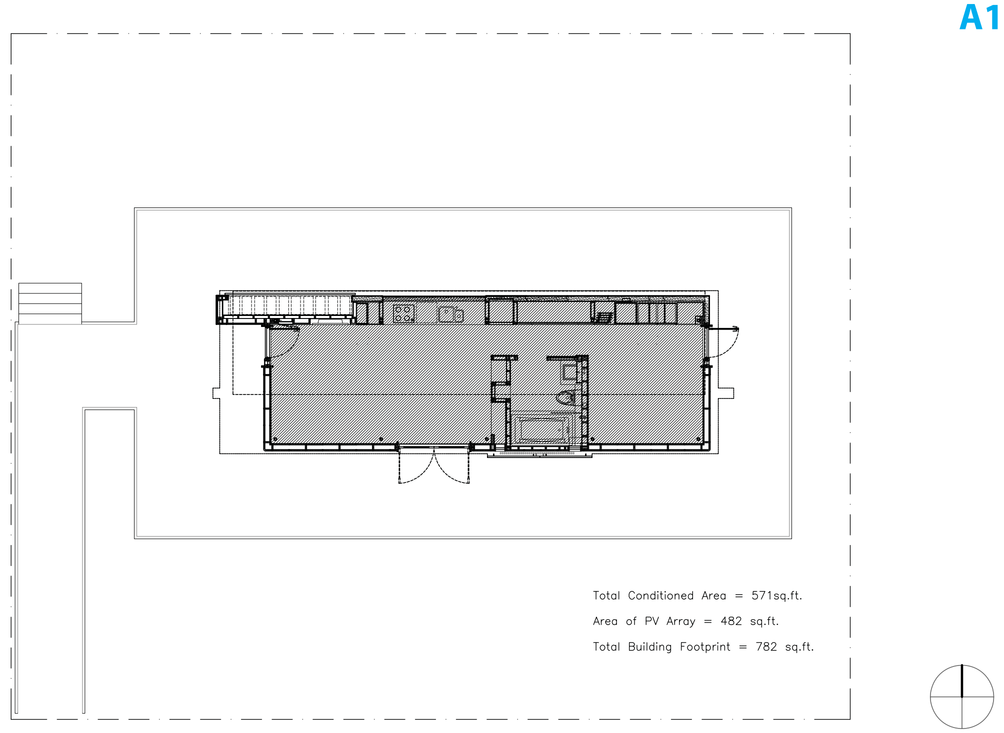
ADA NOTES

- WIDTH OF ALL ENTRIES AND CORRIDOR > 34"
- WIDTH OF HALL > 36"
- WIDTH OF DOORWAYS > 34"
- 5' TURNAROUND CIRCLE PROVIDED IN BATHROOM FOR PUBLIC EXHIBITION
- ALL DOOR THRESHOLDS HAVE LESS THAN 1/4" RISE
- 6'0" RAMP WIDTH FOR 2 WAY CIRCULATION WITH 1:12 SLOPE AND CONTINUOUS HANDRAIL @ 34" HT
- DEPTH OF LANDING > WIDTH OF RAMP
- HEIGHT OF DECK < 30"

A 1.5 TOUR & ADA PLAN
SCALE: 1/8" = 1'-0"

A1.5

A1.6



A 1.6 CONDITIONED AREA PLAN
SCALE: 1/8" = 1'-0"

0 10 20 30

PLANT LIST:

1. CONSTRUCTED SUBSURFACE WETLAND:
Carex nigra - Black Sedge
Iris versicolor -Blue flag Iris
Juncus effusus - Gold Srike Rush
Justica americana - Water willow
Mimulus ringens - Lavendar musk
Panicum dichotomiflorum - Fall panicum
Peltandra virginica - Arrow-arum
Pontederia cordata - Pickerel Rush
Sagittaria latifolia - Arrowhead
Saururus cernuus - Lizard's tail
Typha angustifolia - Narrow leaf Catttail
Zephyranthes candida Rain lily

2. CONSTRUCTED SURFACE WETLAND:
Acorus calamus - Variegated Sweet Flag
Carex nigra - Black Sedge
Iris versicolor - Blue Flag Iris
Hydrocotyle verticillata - Pennywort
Juncus effusus - Gold Srike Rush
Justica americana - Water Willow
Lobelia cardinalis - Cardinal Flower
Mimulus ringens - Lavendar Musk
Myosotis scorpoides - Forget Me Not
Peltandra virginica - Arrow-arum
Pontederia cordata - Pickerel Rush
Sagittaria latifolia - Arrowhead
Saururus cernuus - Lizard's Tail
Typha angustifolia - Narrow Leaf Catttail
Zephyranthes candida - Rain Lily

POND:

3. Open Water:
Ceratophyllum demersum - Hornwort/Coontail
Hydrocotyle verticillata - Pennywort
Nymphoides peltata - Floating Heart

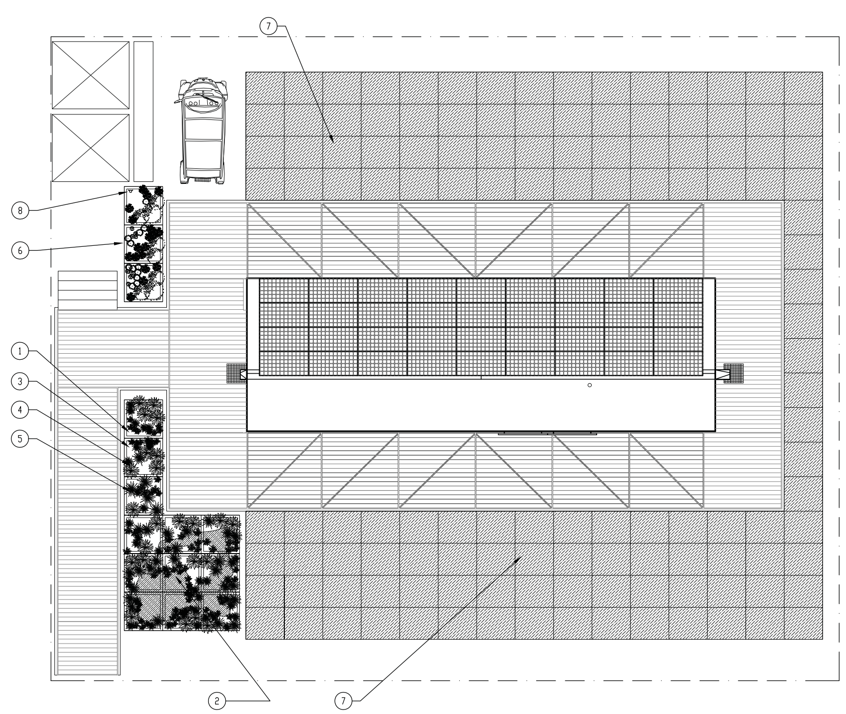
4. Low Marsh:
Acorus calamus - Variegated Sweet Flag
Carex nigra - Black Sedge
Juncus effusus - Gold Srike Rush
Pontederia cordata - Pickerel Rush
Sagittaria latifolia - Arrowhead

5. High Marsh:
Carex nigra - Black Sedge
Iris versicolor -Blue Flag Iris
Lobelia cardinalis - Cardinal Flower
Myosotis scorpoides - Forget Me Not
Rhododendron viscosum - Swamp Azalea
Zephyranthes candida - Rain Lily

6. PLANTERS:
lex verticillata - winterberry holly
Itea virginica - Sweet spire
Gaura lindera - Gaura
Panicum dichotomiflorum - Fall panicum
Schizacharium scoparium - Little Bluestem

7. GRASSES:
Festuca glauca 'Elijah Blue' - Blue Fescue
Festuca rubra - Creeping Red Fescue
Mulhenbergia capillaris - Mully Grass
Panicum virgantum - Switchgrass
Schizacharium scoparium - Little Bluestem

8. IRRIGATION:
Manual Hand Pump:



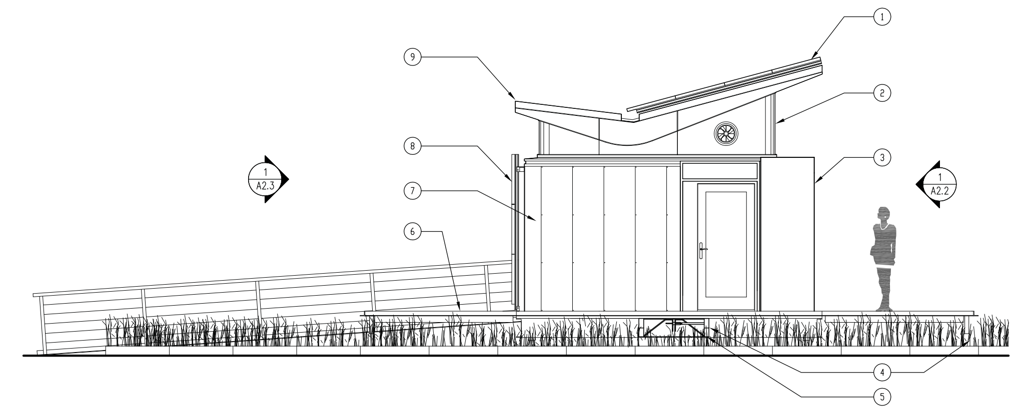
A 1.0 SITE PLAN
SCALE: 1/8" = 1'-0"

0 10 20 30

A1.7

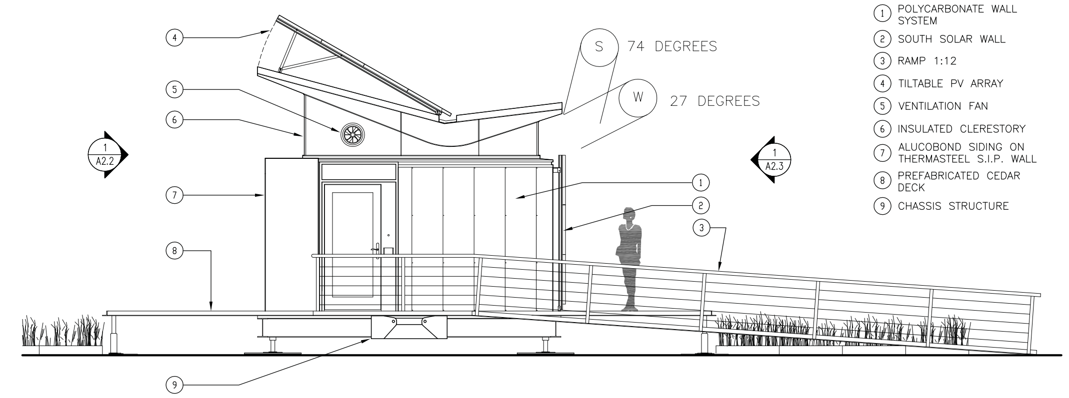
A2.0

1. PHOTOVOLTAIC ARRAY (7.2kw)
2. 1" CLERESTORY INSULATED GLASS
3. ALUMINUM (ALUCOBOND) SIDING ON THERMASTEEL WALL
4. "ENERPAC" FOUNDATION JACKING SYSTEM
5. CHASSIS STRUCTURE BEYOND
6. PREFABRICATED CEDAR DECK
7. POLYCARBONATE WALL SYSTEM
8. SOUTH PV ARRAY
9. WOOD ROOF STRUCTURE



1 A2.0 EXTERIOR ELEVATION - EAST
SCALE: 1/4" = 1'-0"

0 5 10 15



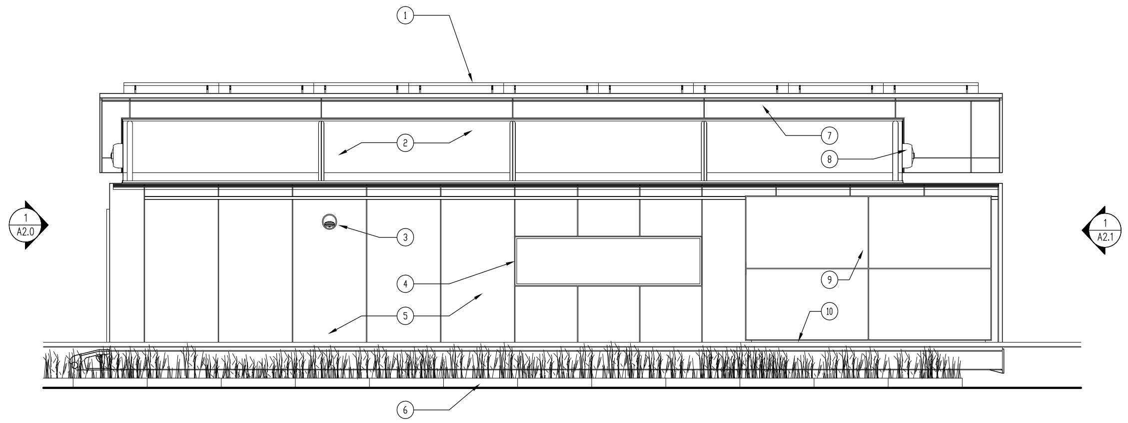
1. POLYCARBONATE WALL SYSTEM
2. SOUTH SOLAR WALL
3. RAMP 1:12
4. TILTABLE PV ARRAY
5. VENTILATION FAN
6. INSULATED CLERESTORY
7. ALUCOBOND SIDING ON THERMASTEEL S.I.P. WALL
8. PREFABRICATED CEDAR DECK
9. CHASSIS STRUCTURE

1 A2.1 EXTERIOR ELEVATION - WEST
SCALE: 1/4" = 1'-0"

0 5 10 15

A2.1

A2.2



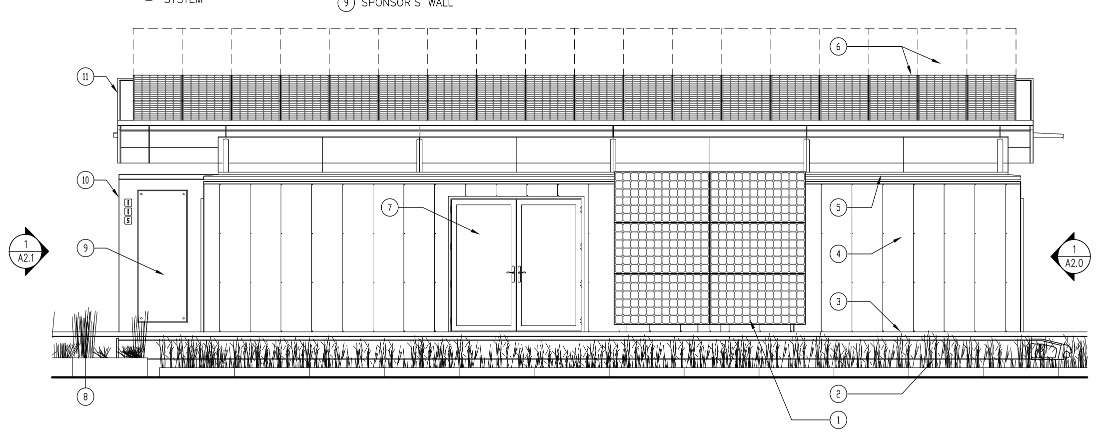
1. TILTABLE PV ARRAY
2. CLERESTORY
3. HEAT EXCHANGER EXHAUST VENT
4. INSULATED KITCHEN GLASS WINDOW
5. ALUCOBOND PANELS ON THERMASTEEL (S.I.P.) CORE
6. LANDSCAPE PLANTERS ON ELEVATED PLATFORMS
7. ALUCOBOND SOFFIT
8. VENTILATION FAN
9. SLIDING ELECT. RM. DOOR
10. PREFABRICATED CEDAR DECK

1 A2.2 EXTERIOR ELEVATION - NORTH

SCALE: 1/4" = 1'-0"

0 5 10 15

1. SOUTH FACING PV SOLAR ARRAY (1.2kw)
2. CHASSIS STRUCTURE BEYOND
3. PREFABRICATED CEDAR DECK
4. POLYCARB INSULATED WALL SYSTEM
5. UPPER DAMPERED VENT WALL CAP
6. 7.2kw PHOTOVOLTAIC ARRAY
7. FULL LITE PATIO DOOR
8. WETLAND PLANTER BEDS ON ELEVATED BASES
9. SPONSOR'S WALL
10. ALUCOBOND CORE
11. MEMBRANE ROOF ON STRESSED SKIN/FOLDED PLATE ROOF STRUCTURE



1 A2.3 EXTERIOR ELEVATION - SOUTH

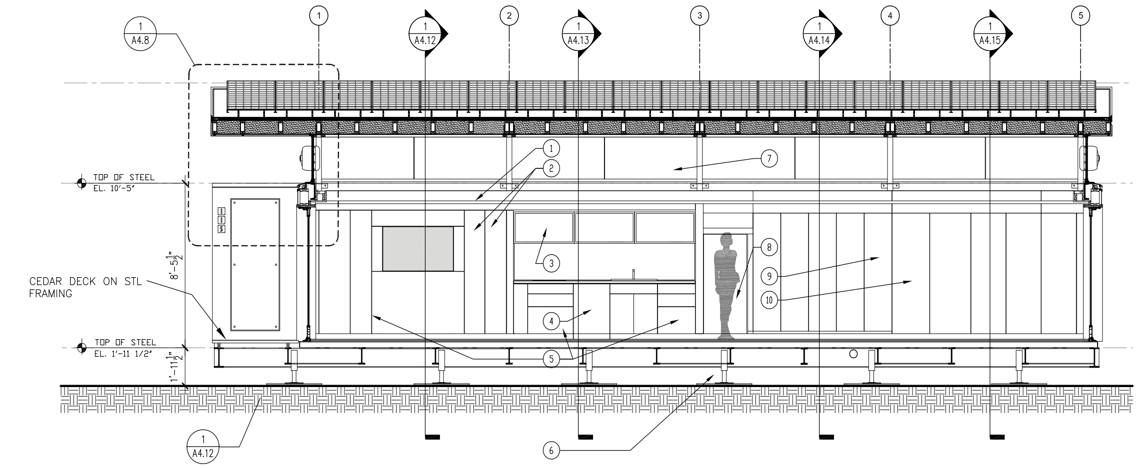
SCALE: 1/4" = 1'-0"

0 5 10 15

A2.3

A3.0

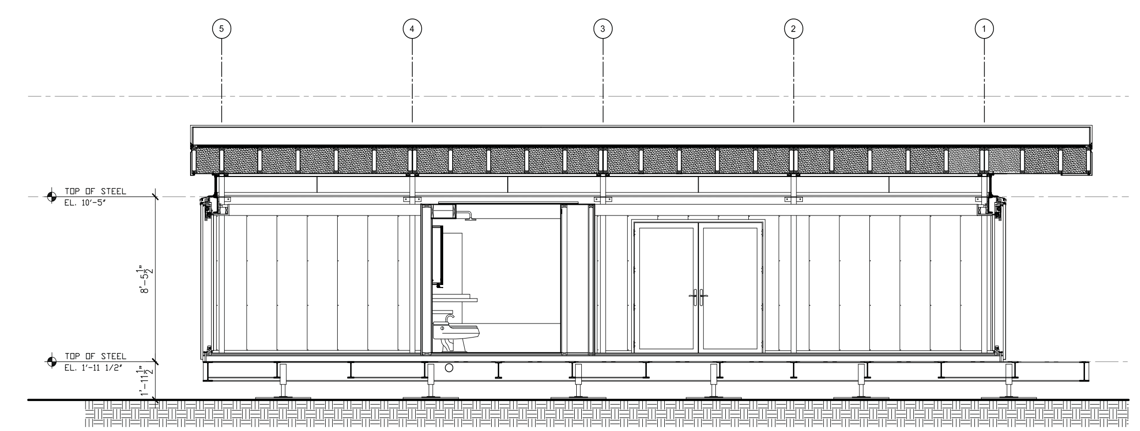
1. VP LIGHTING CONTINUOUS CLG. LIGHT SHELF
2. COAT CLOSET & PANTRY
3. MICROWAVE BEYOND
4. DISHWASHER
5. PLAM PANEL DOORS ON UTILITY CORE WALL
6. FOUNDATION JACKS ON STRUCTURAL PLATFORMS
7. CLERESTORY
8. REFRIGERATOR
9. MECH. SLIDING RM. DOORS W/ PLAM FACE
10. W/D BEYOND



1 A3.0 LONGITUDINAL SECTION - NORTH

SCALE: 1/4" = 1'-0"

0 5 10 15

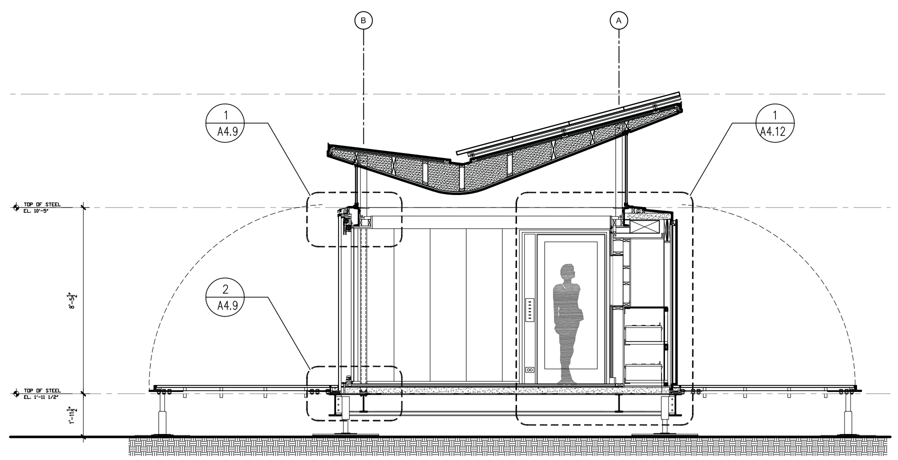


1 A3.1 LONGITUDINAL SECTION - SOUTH

SCALE: 1/4" = 1'-0"

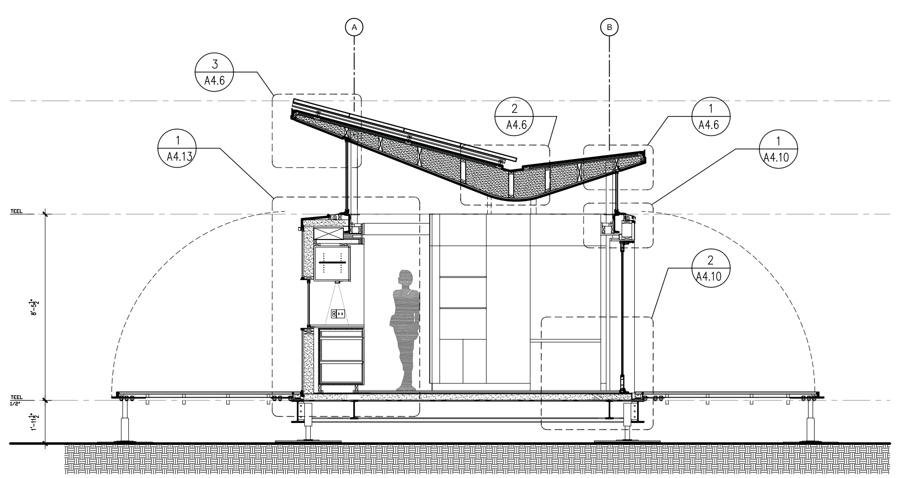
A3.1

A3.2



1 A3.2 SECTION @ ELECTRICAL CLOSET
SCALE: 1" = 1'-0"

0 5 10 15

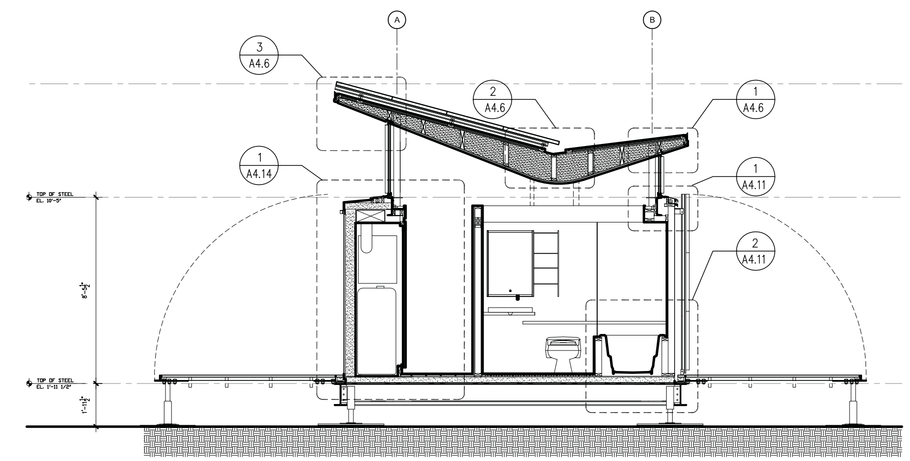


1 A3.3 SECTION @ KITCHEN
SCALE: 1/4 " = 1'-0"

0 5 10 15

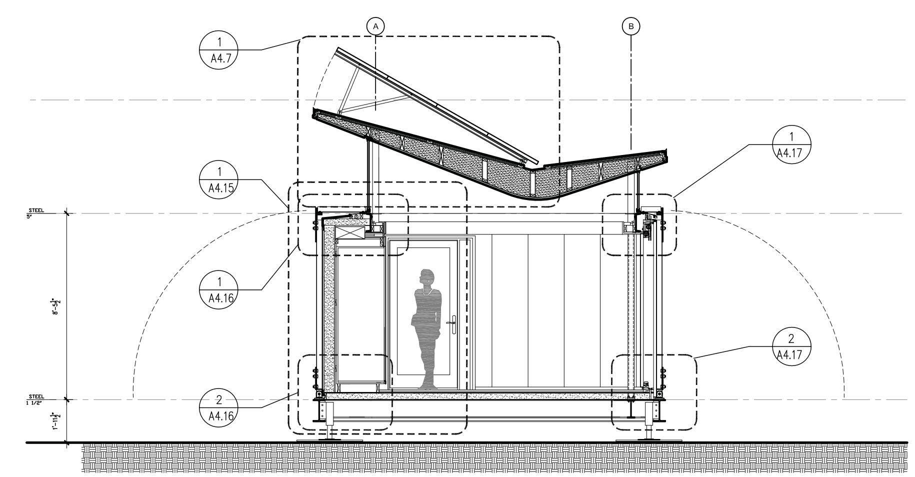
A3.3

A3.4



1 A3.4 SECTION @ BATHROOM
SCALE: 1/4" = 1'-0"

0 5 10 15



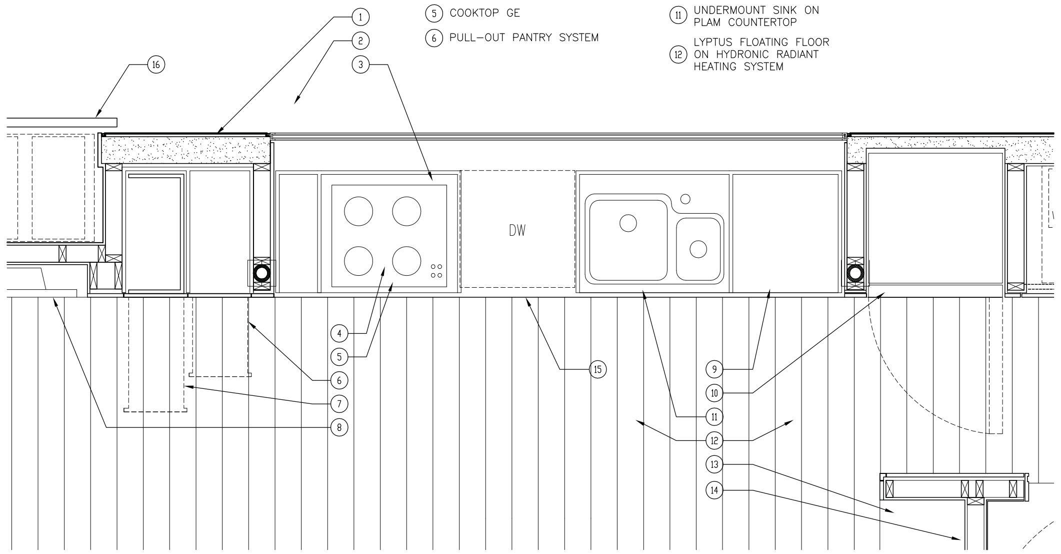
1 A3.5 SECTION @ BEDROOM
SCALE: 1/4" = 1'-0"

0 5 10 15

A3.5

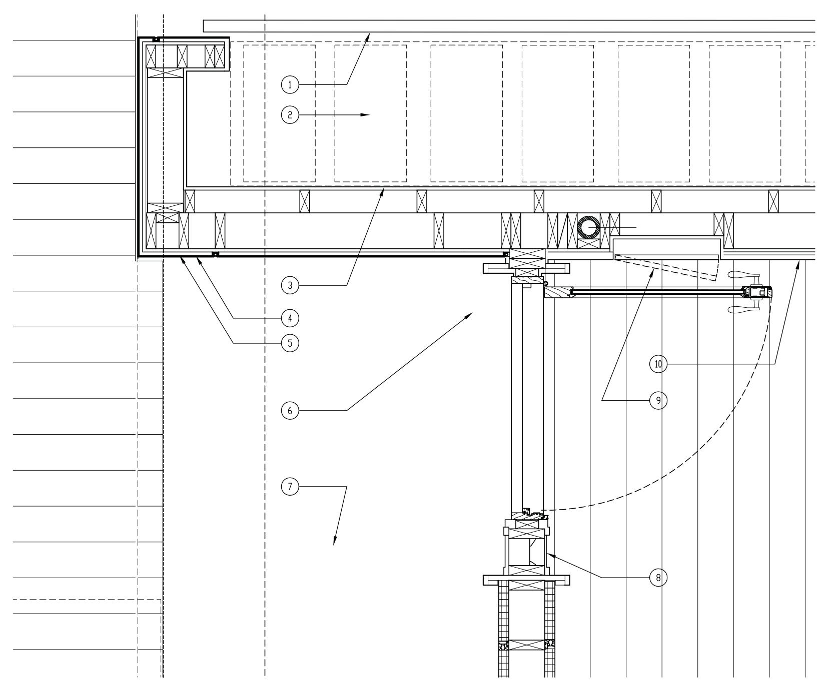
A4.0

1. ALUCOBOND SIDING ON SIP PANEL
2. 1" INSULATED GLASS KITCHEN WINDOW
3. MICROWAVE ABOVE
4. CUPBOARDS ABOVE
5. COOKTOP GE
6. PULL-OUT PANTRY SYSTEM
7. PULL-OUT COAT CLOSET
8. LCD DISPLAY
9. PLAM DOOR FRONTS TO MATCH CORE WALL
10. 16 cu.ft. REFRIGERATOR
11. UNDERMOUNT SINK ON PLAM COUNTERTOP
12. LYPTUS FLOATING FLOOR ON HYDRONIC RADIANT HEATING SYSTEM
13. AV CLOSET W/ ELECTRONIC KEY OPERATION
14. DECORATIVE COLOR MDF PANEL W/ CNC PATTERN DOWNLIT
15. DW W/ PLAM INSERT TO MATCH CORE WALL



1 A4.0 PLAN DETAIL- KITCHEN
SCALE: 3/4" = 1'-0"

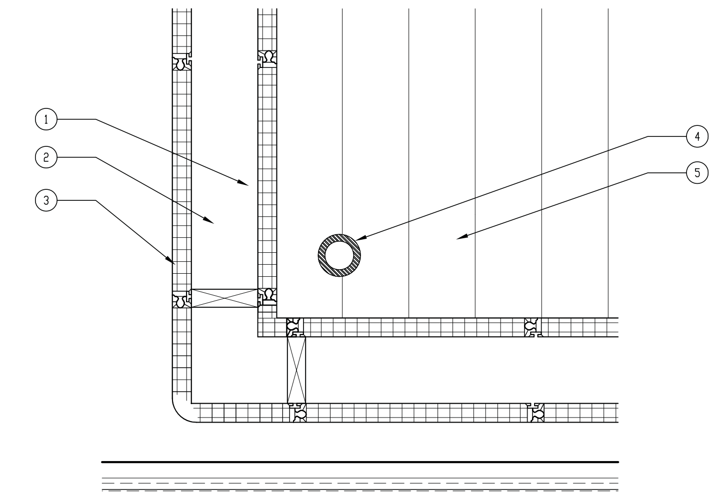
1. SLIDING ELECT. ROOM DOOR
2. BATTERY RACK
3. 2 HR RATED WALL
4. SPONSORS WALL
5. LED ILLUMINATED HOUSE NUMBERS "SPORE INC."
6. FULL LITE INSWING FRONT DOOR IN "EYEBROW" FRAME
7. CEDAR DECK
8. LIGHTING CONTROL PANEL
9. BREAKER PANEL CLOSET
10. PLAM PANELS ON "CORE" FACE – TYP.



1 A4.1 PLAN DETAIL- ENTRY
SCALE: 1" = 1'-0"

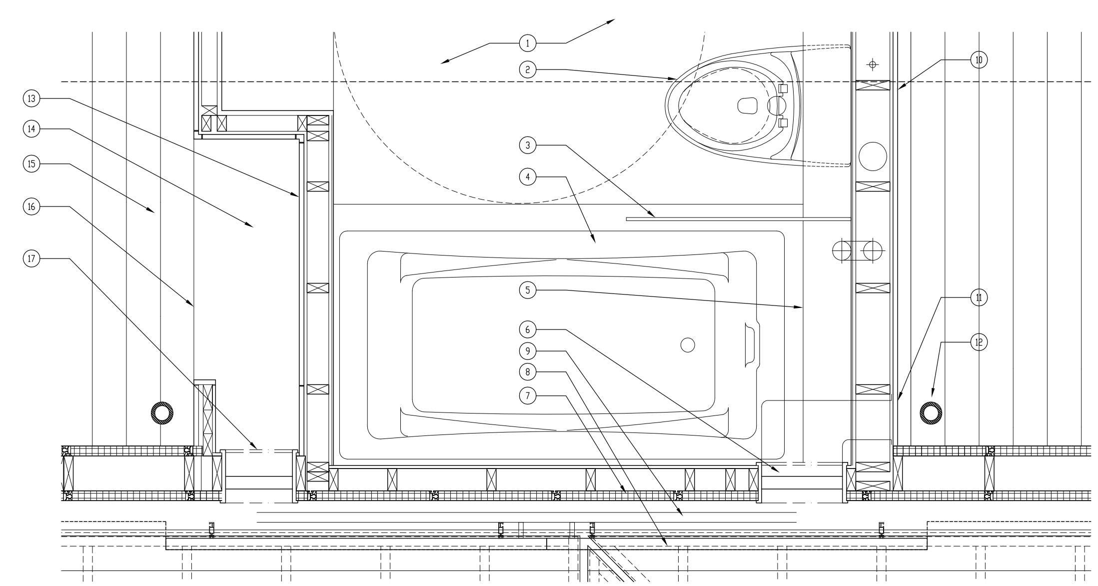
A4.1

A4.2



1. TUNABLE L.E.D. COLORCAST FIXTURES
2. OPERABLE DAMPERS W/ ELECT. LINEAR ACTUATORS – TYP. EWS WALLS
3. 40 MIN. AEROGEL FILLED POLYCARB PANEL ON CONVENTIONAL 2x6 FRAMING
4. STL. COLUMN W/ SHERCRYL FINISH
5. ELECT. FLOOR OUTLET
6. LYPTUS HARDWOOD FLOOR

1 A4.2 PLAN DETAIL- SOUTHWEST CORNER
SCALE: 1 1/2" = 1'-0"



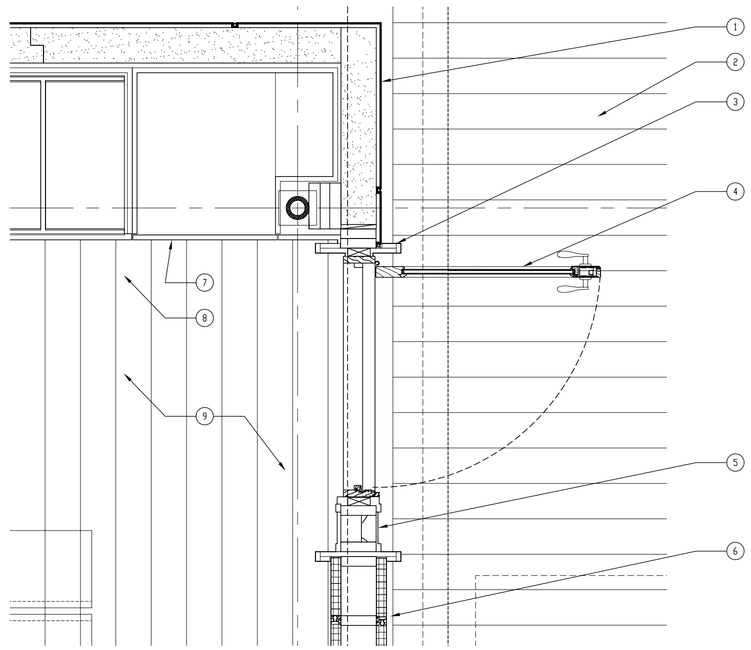
1. RECYCLED GLASS TILE
2. HIGH EFFICIENCY DUAL FLUSH TOILET
3. TEMP. GLASS WALL
4. KOHLER TUB C.I.
5. SHOWER SHELF ABOVE
6. MOTORIZED DAMPER BELOW
7. RECYCLED GLASS TILE ON 1/2" GREEN BD. ON 2x4 FRAMING W/ ICYNENE INSULATION
8. SOUTH PV ARRAY
9. SLIDING AEROGEL FILLED POLYCARB WALL
10. MAPLE VENEER PLYWOOD ON 2x6 WALL
11. MECH. GRILLE
12. STEEL COLUMN
13. CNC ROUTED DECORATIVE PANEL
14. COMPUTER
15. KEYBOARD TRAY
16. PLAM COUNTERTOP
17. MECH. GRILLE

1 A4.3 PLAN DETAIL- BATH
SCALE: 1" = 1'-0"

A4.3

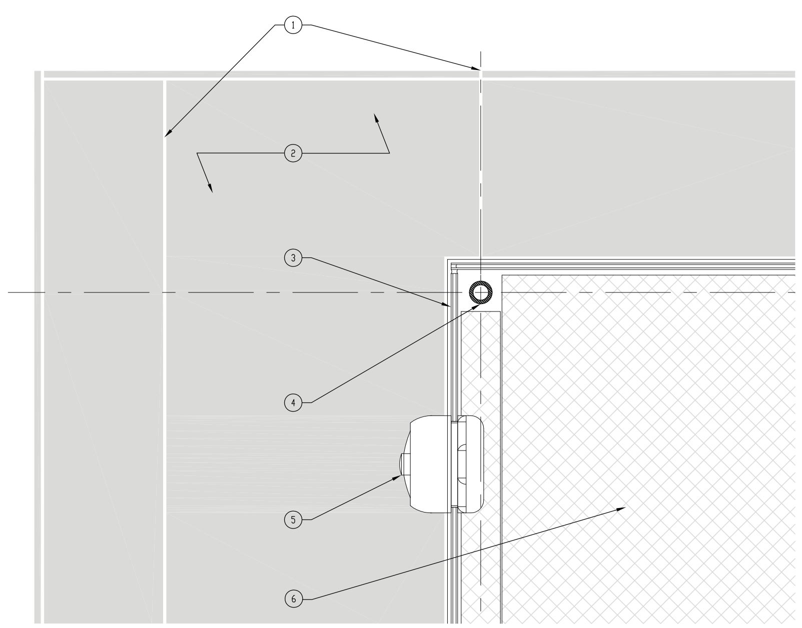
A4.4

1. ALUCOBOND SIDING ON 5 1/2" THERMASTEEL WALL S.I.P.
2. PREFABRICATED CEDAR DECK PANELS
3. BIRCH PLYWOOD EYEBROW
4. OUTSWINGING FULL LITE FRENCH DOOR W/ ELECTRONIC DOOR LOCKING DEVICE
5. SWITCH PANEL (INT.)
6. AEROGEL FILLED POLYCARBONATE PANEL ON CONVENTIONAL 2x6 FRAMING
7. FULL AT CLOSET W/ DOUBLE HANGER RODS. ALL CABINETS MADE OF DOW "WOODSTALK" MATERIAL
8. SLIDING SHELF CABINETS OF WOODSTALK MATL.
9. LYPTUS FLOORING



1 A4.4 PLAN DETAIL- BEDROOM DOOR
SCALE:

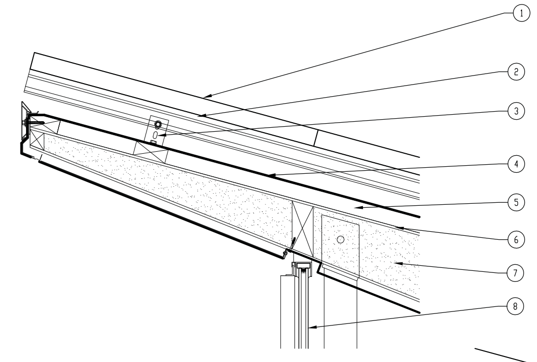
1. 1/2" CAULK JOINT
2. ALUCOBOND PANELS
3. GLASS CLERESTORY
4. COLUMN
5. VENTAXIA FAN
6. MECHOSHADE NYLON FABRIC



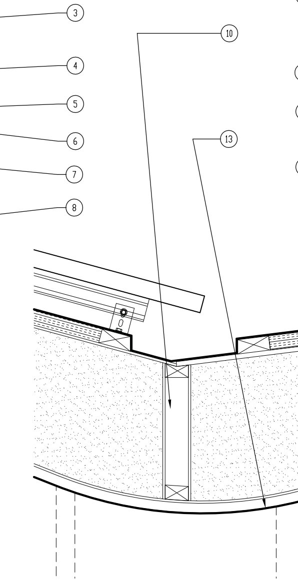
1 A4.5 REFLECTED CEILING PLAN DETAIL- ENTRY
SCALE: 1 1/2" = 1'-0"

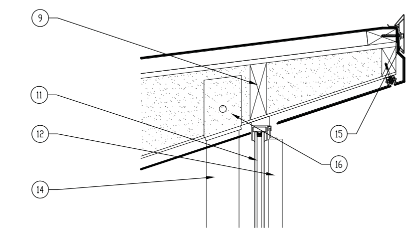
A4.5

A4.6



1. PHOTOVOLTAIC
2. UNIRACK RAIL
3. UNIRACK CLIP
4. WATERPROOF MEMBRANE
5. RIGID INSULATION
6. STRESSED SKIN PLYWOOD
7. EXPANDED POLYICYNENE INSULATION
8. GLASS CLERESTORY





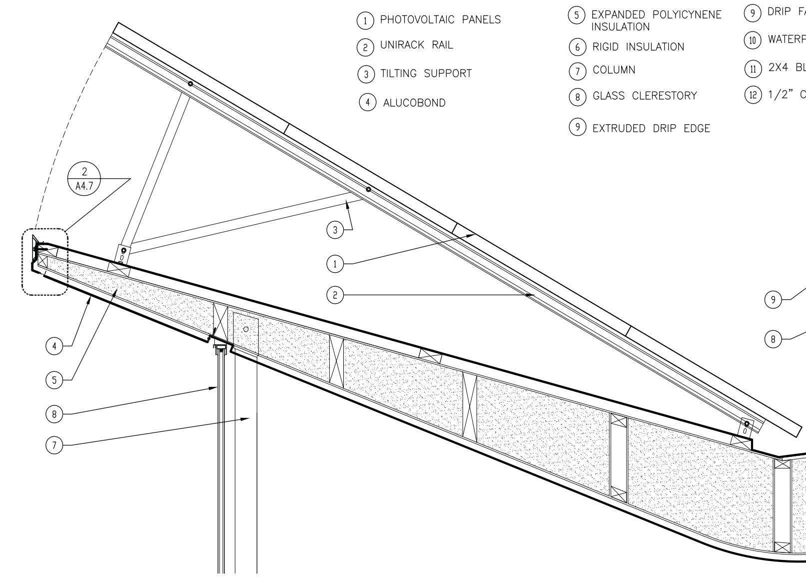
9. P-LAM BEAM
10. BOX BEAM
11. ALUCOBOND
12. TEMPORARY THERMAL PANEL
13. NYLON FABRIC
14. COLUMN
15. DRIP EDGE
16. COLUMN CAP WITH BOLT

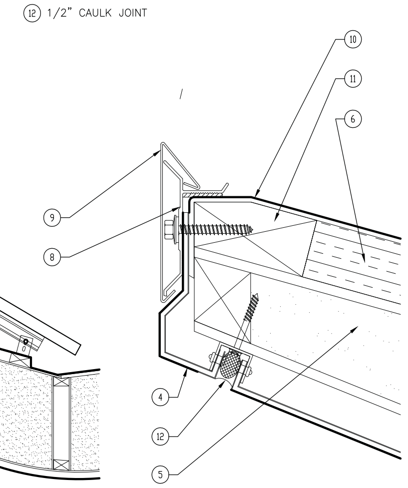
3 A4.6 ROOF SECTION
SCALE: 1 1/2" = 1'-0"

2 A4.6 ROOF SECTION
SCALE: 1 1/2" = 1'-0"

1 A4.6 ROOF SECTION
SCALE: 1 1/2" = 1'-0"

1. PHOTOVOLTAIC PANELS
2. UNIRACK RAIL
3. TILTING SUPPORT
4. ALUCOBOND
5. EXPANDED POLYICYNENE INSULATION
6. RIGID INSULATION
7. COLUMN
8. GLASS CLERESTORY
9. EXTRUDED DRIP EDGE
9. DRIP FASCIA
10. WATERPROOF MEMBRANE
11. 2X4 BLOCKING
12. 1/2" CAULK JOINT





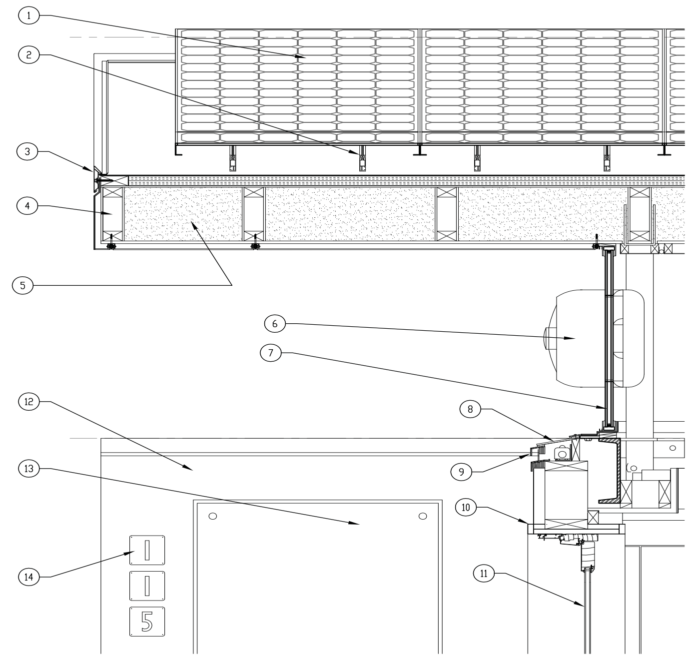
1 A4.7 SECTION- PHOTOVOLTAIC TILT
SCALE: 1" = 1'-0"

2 A4.7 EDGE DETAIL
SCALE: 3" = 1'-0"

A4.7

A4.8

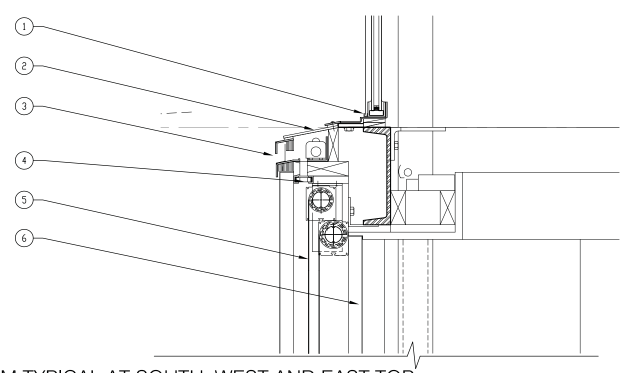
1. PHOTOVOLTAIC PANELS
2. UNIRACK RAILS
3. DRIP EDGE
4. BOX BEAM
5. EXPANDED POLYICYNENE INSULATION
6. VENTAXIA FAN
7. GLASS CLERESTORY
8. PLEXIGLASS COVER
9. ALUCOBOND DRIP EDGE
10. EYEBROW WOOD FRAME
11. DOOR
12. ALUCOBOND
13. DONOR WALL
14. ADDRESS PANEL NUMBERS



1 A4.8 WALL SECTION- ENTRY

SCALE: 1 1/2" = 1'-0"

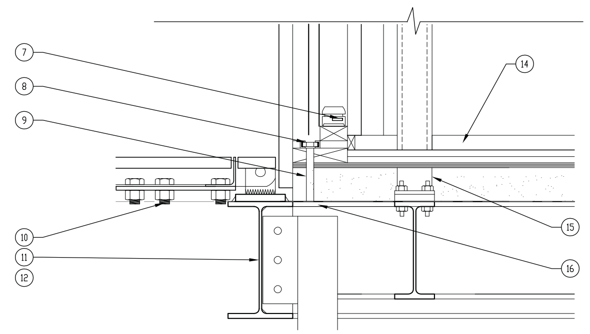
1. CONT. TRACK FOR REMOVEABLE INSULATION
2. PLEXIGLASS COVERED FLUORESCENT LIGHT COVE
3. VENTED FASCIA FOR LIGHT FIXTURE CAVITY & OPERABLE DAMPER
4. PATIO DOOR "EYEBROW" FRAME
5. 2 PANEL FRENCH DOOR @ PATIO
6. PREFAB CEDAR DECK
7. COL. BEYOND
8. CONT. DIMMABLE FLUORESCENT
9. POPLAR LIGHTSHELF



1 A4.9 WALL SECTION- BEDROOM TYPICAL AT SOUTH, WEST AND EAST TOP

SCALE: 1-1/2" = 1'-0"

9. VENTS THRU FLOOR TO UNDERSIDE OF CHASSIS
10. COLLAPSABLE TRUSS SYSTEM AS FRAMEWORK FOR PREFAB CEDAR DECK
11. CHASSIS
12. ENERPAC HYDRAULIC FOUNDATION SYSTEM
13. DIMMABLE FLUORESCENT FIXTURE ON POPLAR LIGHTSHELF
14. F.F. ON REHAU HYDRONIC RADIANT FLOOR SYSTEM – SEE SHEET M2
15. STEEL COL. ATT TO CHASSIS W/ W.D. THERMAL BREAK PAD
16. BUG SCREEN



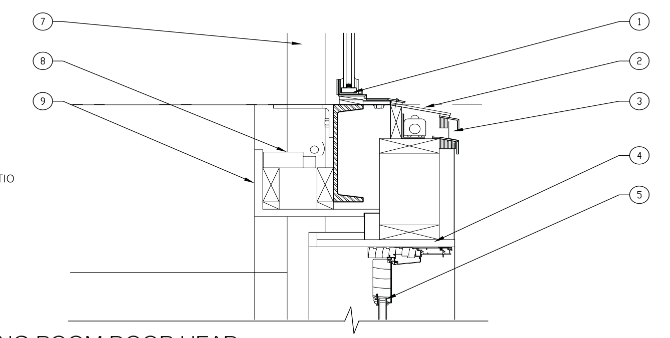
2 A4.9 WALL SECTION- BEDROOM TYPICAL AT SOUTH, WEST AND EAST BOTTOM

SCALE: 1-1/2" = 1'-0"

A4.9

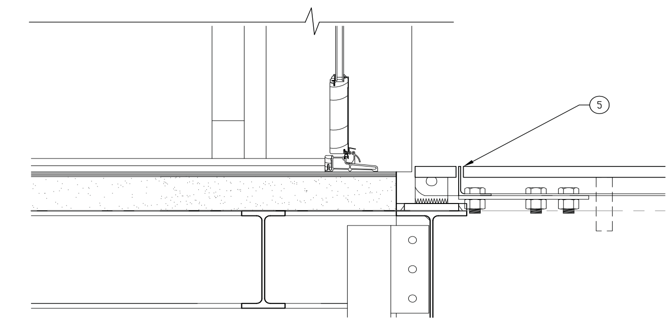
A4.10

1. CONT. TRACK FOR REMOVEABLE INSULATION
2. PLEXIGLASS COVERED FLUORESCENT LIGHT COVE
3. VENTED FASCIA FOR LIGHT FIXTURE CAVITY & OPERABLE DAMPER
4. PATIO DOOR "EYEBROW" FRAME
5. 2 PANEL FRENCH DOOR @ PATIO
6. PREFAB CEDAR DECK
7. COL. BEYOND
8. CONT. DIMMABLE FLUORESCENT
9. POPLAR LIGHTSHELF



1 A4.10 WALL SECTION- DINING ROOM DOOR HEAD

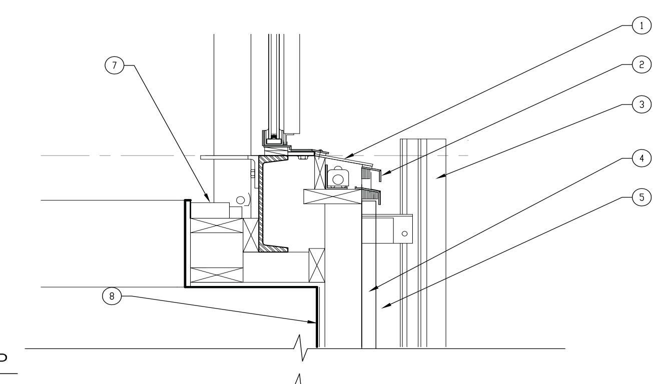
SCALE: 1-1/2" = 1'-0"



2 A4.10 WALL SECTION- DINING ROOM DOOR SILL

SCALE: 1-1/2" = 1'-0"

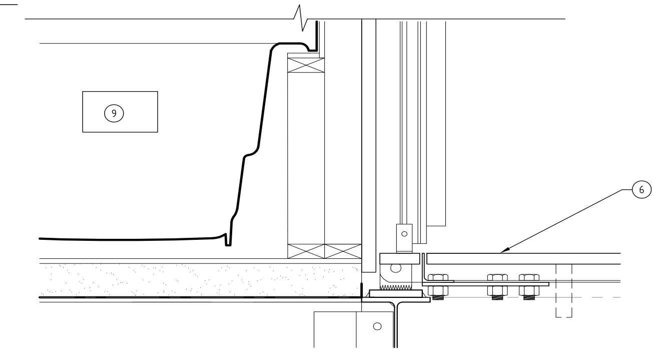
1. PLEXIGLASS COVERED FLUORESCENT LIGHT COVE
2. ALUCOBOND DRIP EDGE
3. SOUTH FACING PV ARRAY 1.2 KW
4. 4 SLIDING AEROGEL FILLED POLYCARB PANEL FOR SOUTH PATIO DOOR COVER
5. UNIRAC PV STRUTS
6. PREFAB CEDAR DECK



1 A4.11 WALL SECTION- BATH TOP

SCALE: 1-1/2" = 1'-0"

7. LIGHTSHELF
8. RECYCLED GLASS TILE ON 1/2" GWB ON 2X4 STUDS W/ ICYNENE INSULATION
9. DAMPER/VENT BEYOND



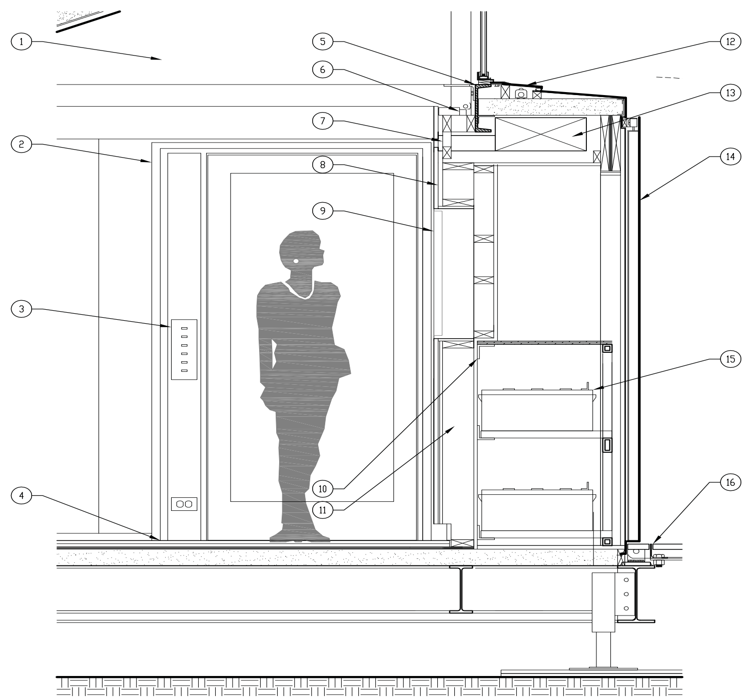
2 A4.11 WALL SECTION- BATH BOTTOM

SCALE: 1-1/2" = 1'-0"

A4.11

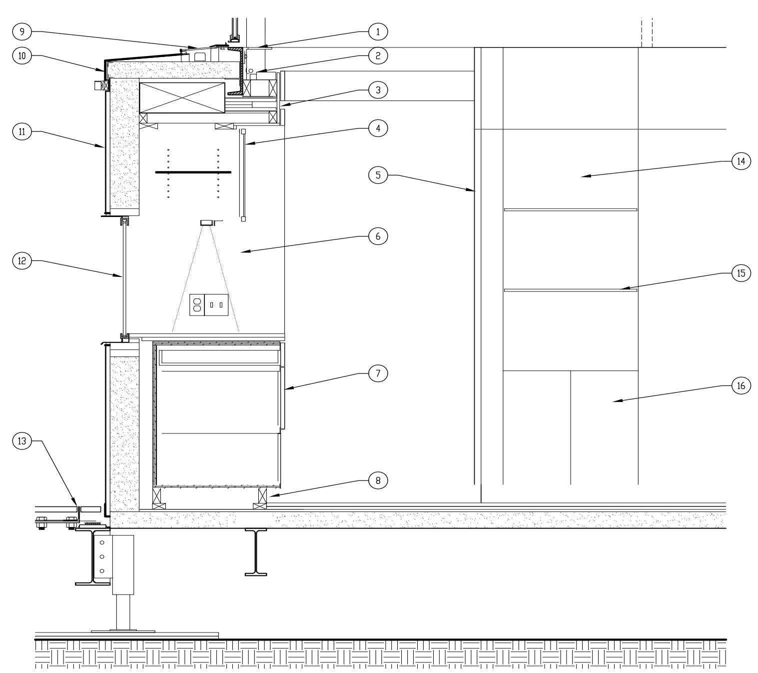
A4.12

1. CLERESTORY BEYOND 1" INSUL. GLASS
2. "EYEBROW" DOOR FRAME
3. LIGHTING CONTROL PANEL
4. "LYPTUS" ENGINEERED FLOATING FINISH FLOOD ON HYDRONIC RADIANT FLOOR SYSTEM ON 1/2" STRUCTURE BOARD ON THERMOSTEEL DECK
5. CONTINUOUS CLERESTORY ON C STEEL MOMENT RESISTANT FRAME STRUCTURE
6. CONT. FLOURESCENT FIXTURES ON LIGHTSHELF
7. CONT. LINEAR DIFFUSER BY TITUS
8. P-LAM PANEL & DOOR FRONTS TYP ON NORTH "CORE" INTERIOR
9. LCD DISPLAY
10. 2 HR RATED WALL
11. ICYNENE INSULATION
12. CONT. FLUORESCENT "DAMP LOCATION LT FIXTURE
13. MECH SUPPLY DUCT
14. SLIDING ELECT DOOR
15. BATTERY TYP OF 20
16. PREFAB CEDAR DECK FRAME



1 / 4.12 WALL SECTION- ELECTRICAL CLOSET
SCALE: 3/4" = 1'-0"

1. MOMENT RESISTANT STEEL CONNECTION OF FRAME TO COL
2. LIGHTSHELF
3. CONT. LINEAR DIFFUSER
4. GLASS CUPBOARD DOORS TYP OF 3 BY "HAEFELE"
5. MAPLE VENEERED "APPLE PLY" TYP. @ BATH CORE EXT. 3 SIDES
6. GWB PAINTED
7. P-LAM DOORS & FACE PANES TYP @ INT. FACE OF "CORE" WALL
8. BASEBOARD
9. CONT. FLUORESCENT LIGHT STRIP
10. ALUCOBOND DRIP EDGE OVER CONT. ELEC. DOOR TRACK
11. ALUCOBOND ON THERMOSTEEL WALL 5-1/2" R22
12. KITCHEN INSULATED GLASS WINDOW
13. COLORED MDF DECORATIVE PANEL (DOWN LIT)
14. PREFAB CEDAR DECK
15. GLASS SHELVES
16. AV CABINET W/ ELECTRONIC LOCK SYSTEM

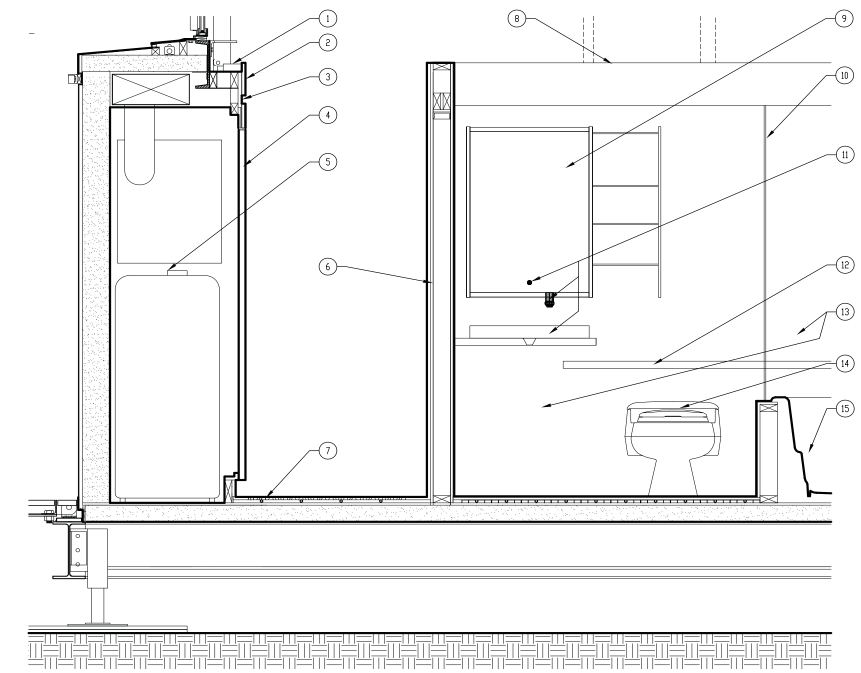


1 / 4.13 WALL SECTION- KITCHEN
SCALE: 3/4" = 1'-0"

A4.13

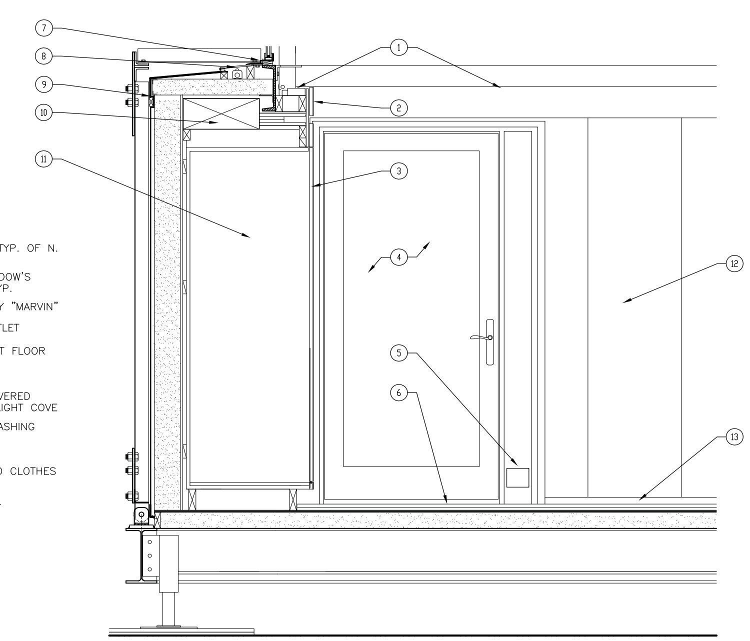
A4.14

1. CONT. LIGHTSHELF
2. P-LAM PANELS TYP. OF N. WALL
3. CONTINUOUS LINEAR DIFFUSER
4. SLIDING MECH DOORS
5. WATER TANKS (2)
6. SLIDING GLASS BATH DOOR (ACID ETCHED)
7. F.F. ON RADIANT FLOOR
8. POLYCARBONATE CEILING
9. MIRROR CABINET
10. TEMPERED GLASS PARTITION
11. MIRROR FAUCET W/ WET SURFACE LAVATORY BY "KOHLER"
12. COUNTERTOP
13. TILE GLASS RECYCLED
14. TUB "KOHLER"



1 / 4.14 WALL SECTION-MECHANICAL CLOSET
SCALE: 3/4" = 1'-0"

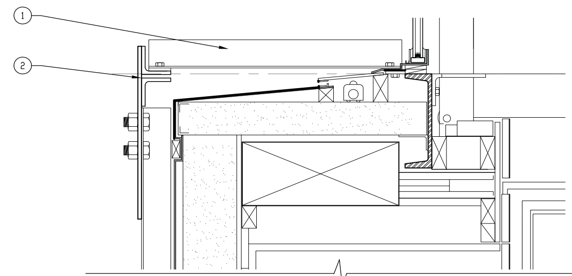
1. LIGHTSHELF
2. P-LAM PANEL TYP. OF N. WALL INT.
3. CABINETRY OF DOW'S WHEATBOARD TYP.
4. GLASS DOOR BY "MARVIN"
5. ELECTRICAL OUTLET
6. F.F. ON RADIANT FLOOR
7. CLERESTORY
8. PLEXIGLASS COVERED FLUORESCENT LIGHT COVE
9. ALUCOBOND FLASHING
10. MECH. DUCT
11. DOUBLE LOADED CLOTHES HANGER
12. POLYCARB WALL
13. BASEBOARD



1 / A4.15 WALL SECTION- BEDROOM CLOSET
SCALE: 3/4" = 1'-0"

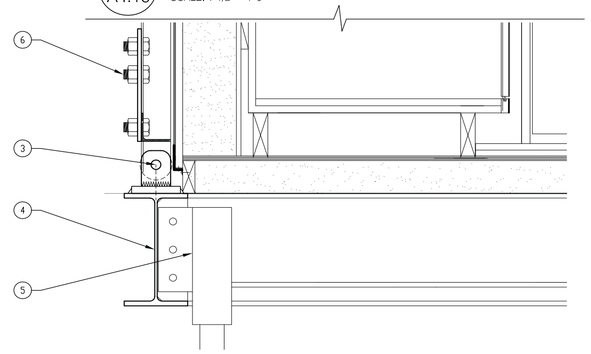
A4.15

A4.16



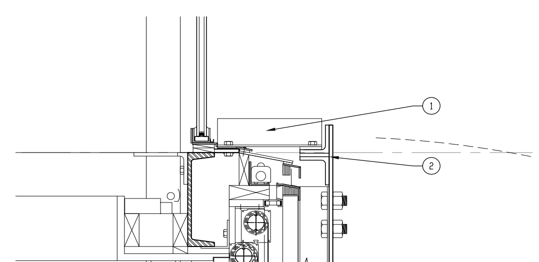
① STEEL "LACING" FOR TOP OF TRUSS SUPPORT DURING TRANSPORT
② STEEL TRUSS IN VERTICAL "TRAVEL" MODE
③ STRUCTURAL HINGE CONNECTING TRUSS TO CHASSIS
④ CHASSIS STRUCTURE BELOW
⑤ ENERPAC FOUNDATION JACKS IN "UP" POSITION
⑥ 1" BOLTS FULLY TIGHTENED

1 A4.16 TRUSS- BUILDING IN TRANSPORT MODE- SOUTH TOP
SCALE: 1-1/2" = 1'-0"

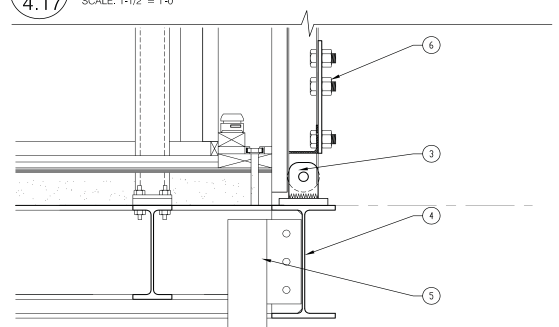


2 A4.16 TRUSS- BUILDING IN TRANSPORT MODE- SOUTH BOTTOM
SCALE: 1-1/2" = 1'-0"

① STEEL "LACING" FOR TOP OF TRUSS SUPPORT DURING TRANSPORT
② STEEL TRUSS IN VERTICAL "TRAVEL" MODE
③ STRUCTURAL HINGE CONNECTING TRUSS TO CHASSIS
④ CHASSIS STRUCTURE BELOW
⑤ ENERPAC FOUNDATION JACKS IN "UP" POSITION
⑥ 1" BOLTS FULLY TIGHTENED



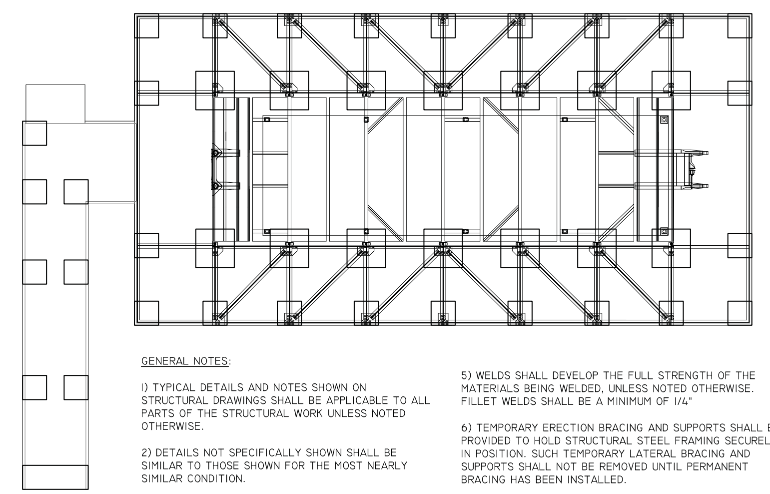
1 4.17 SECTION-BUILDING IN TRANSPORT MODE- NORTH TOP
SCALE: 1-1/2" = 1'-0"



2 4.17 SECTION-BUILDING IN TRANSPORT MODE- NORTH BOTTOM
SCALE: 1-1/2" = 1'-0"

A4.17

S1.0



FOUNDATION NOTES:

1) STUCTURE TO BE SUPPORTED BY EXTERIOR MOUNTED HYDRAULIC JACKS WITH 3'-0" x 3'-0" FOOTINGS BENEATH.

2) NO RESPONSIBILITY IS ASSUMED BY THE ARCHITECT OR ENGINEER FOR THE VALIDITY OF THE SUBSURFACE CONDITIONS ASSUMED FOR DESIGN.

3) FOOTINGS SHALL BE CENTERED UNDER SUPPORTED STRUCTURAL MEMBERS, UNLESS NOTED OTHERWISE.

GENERAL NOTES:

1) TYPICAL DETAILS AND NOTES SHOWN ON STRUCTURAL DRAWINGS SHALL BE APPLICABLE TO ALL PARTS OF THE STRUCTURAL WORK UNLESS NOTED OTHERWISE.

2) DETAILS NOT SPECIFICALLY SHOWN SHALL BE SIMILAR TO THOSE SHOWN FOR THE MOST NEARLY SIMILAR CONDITION.

3) STRUCTURAL STEEL WORK SHALL CONFORM TO "SPECIFICATION FOR STRUCTURAL STEEL BUILDINGS (AISC 1999);" "CODE OF STANDARD PRACTICE FOR STEEL BUILDINGS & BRIDGES (AISC 1992);" AND "STRUCTURAL WELDING CODE - STEEL (AWS D1.1-96)."

4) WELDED CONNECTIONS SHALL BE MADE BY APPROVED CERTIFIED WELDERS USING FILLER METAL CONFORMING TO E70XX.

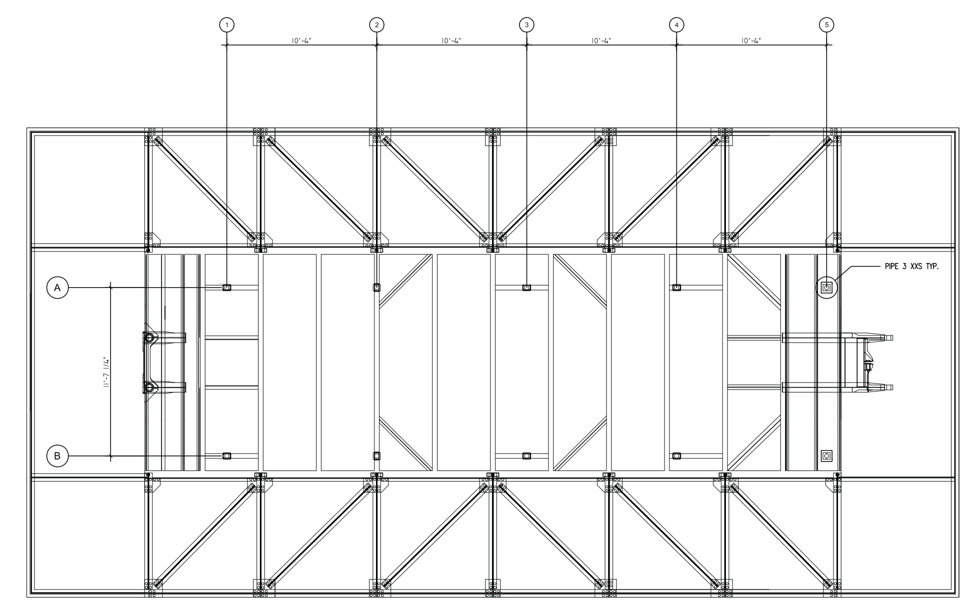
5) WELDS SHALL DEVELOP THE FULL STRENGTH OF THE MATERIALS BEING WELDED, UNLESS NOTED OTHERWISE. FILLET WELDS SHALL BE A MINIMUM OF 1/4"

6) TEMPORARY ERECTION BRACING AND SUPPORTS SHALL BE PROVIDED TO HOLD STRUCTURAL STEEL FRAMING SECURELY IN POSITION. SUCH TEMPORARY LATERAL BRACING AND SUPPORTS SHALL NOT BE REMOVED UNTIL PERMANENT BRACING HAS BEEN INSTALLED.

7) STRUCTURAL STEEL FRAMING SHALL BE TRUE AND PLUMB BEFORE CONNECTIONS ARE FINALLY BOLTED OR WELDED.

8) ASSUMED STRUCTURAL DESIGN LOADS ARE AS FOLLOWS:
A) DEAD LOAD - AS REQUIRED
B) LIVE LOAD - 100 PSF (CORRIDOR LOADING)
C) WIND LOAD - PER ASCE 7-02 MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES (CHAPTER 6.0), WITH A DESIGN WIND VELOCITY OF 90 MPH.
D) SNOW LOAD - 25 PSF

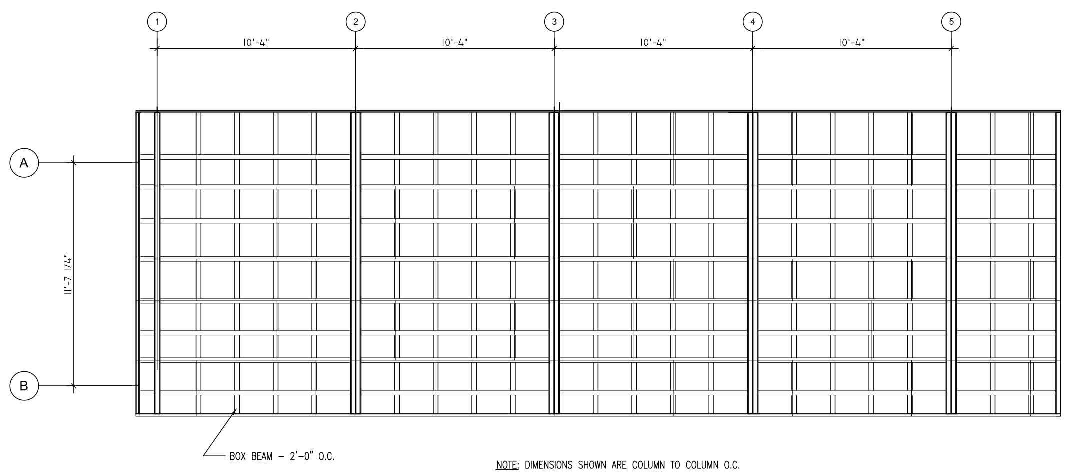
1 S1.0 FOUNDATION PLAN
SCALE: 1/8" = 1'-0"



1 S1.1 STRUCTURAL PLAN
SCALE: 1/4" = 1'-0"

S1.1

S1.2



1 / S1.2 ROOF FRAMING PLAN
SCALE: 1/4" = 1'-0"

ARRIVAL AND DEPARTURE PLAN

(House dissassembled in reverse order)

1. Staging Area - Midnight, Sept. 28th
The truck and house arrive at the designated staging area, awaiting its time to move onto the Mall. The house is thoroughly inspected for damage and strains from the trip. Preparations for repairs or adjustments will be made, to be carried out on the Mall.

2. Site Preparations - Day 1
The house site is prepared for the truck. Plywood and mats are arranged on the grass to minimize damage to the mall. The foundation system is set out and readied for installation.

3. House Arrival - Day 1
The truck and house arrive on the Mall and drive onto the site. The house is positioned as shown in the Site Plan.

4. HOUSE FOUNDATION - DAY 1
The house is pneumatically lifted using the trucking transport components attached to the house. Intermediate high-capacity bottle jacks are placed at the corners of the house and take the house load. The transportation components are detached from the house and moved away. The Enerpac foundation jacks and pads are placed under the house chassis and surveyed for levelness. The house is lowered and the foundation now takes the full load of the house.

5. TRUSSES LOWERED/DECK INSERTED - DAY 1
The deck foundations are surveyed and placed. The trusses are unbolted from the house and lowered onto its foundations. The prefabricated deck inserts are driven onto the site and laid in place. Deck steps and ramp are installed. Areas covering water tank locations are left open for tank installation.

6. Transit Bracing/Damage Check - Day 1
House wrapping is removed and doors are opened. Interior cross-bracing cables and other shipping supports are removed and house is checked for damage due to travel. Floor, finish walls, doors, glass, roof, lighting systems, and structural system are all thoroughly checked for damage or movement. Any necessary repairs or adjustments will me made before continuing with the house setup.

7. Power Installation - Day 2
The PV arrays and mounting racks are driven onto the site and attached to the roof. The PVs are wired up to each other and connected to the main roof junction. The batteries are driven onto the site and installed in the rack. Electric panels and power management equipment are turned on and checked.

8. Water Tanks - Day 2
The water storage tanks are placed under the house and plumbed. All plumbing fixtures and fittings are checked and pressurized with air. Once the system passes the leak tests, it is filled and run.

9. MEchanical Systems - Day 2
Any appliances that were not shipped in the house are installed. All mechanical systems are unpacked from their shipping state, connected to the house system, and tested for working.

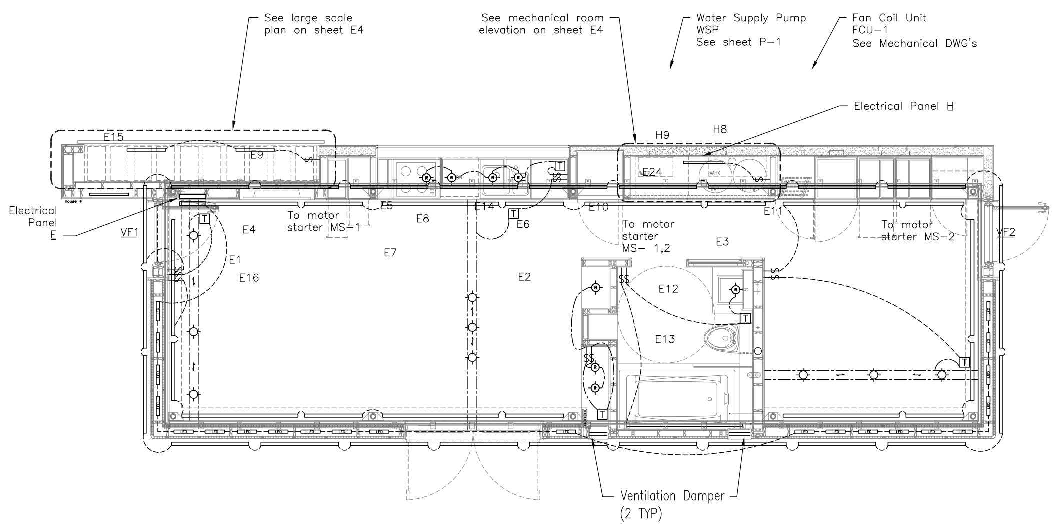
10. Interiors - Day 2
Furniture and kitchenware are moved into the space and setup for exhibit. Computer monitoring systems are brought in and tested for control of house. Lighting systems are tested, audio/visual equipment tested.

11. SITE WORK - DAY 2+3
Landscaping brought in on trucks, and installed. Grey water system is built and filled. Queuing area and exhibit structure are built. The exhibit media is unpacked and arranged. The electric car is brought to the site and placed. Remaining site work is finished, including landscaping, queuing area, and exhibit area.

12. HOUSE COMPLETE - DAY 3
A final walkthrough of the house is made, noting any adjustments or problems needing resolution. The house systems are continuously monitored and adjusted as needed. Walk-around of the house is made, checking the envelope, deck, and wall-mounted PVs. A walk-around of the site is made, checking the landscape, outdoor structures and general site. 2 days remain for unexpected setbacks and repairs.

S1.3

E1.0



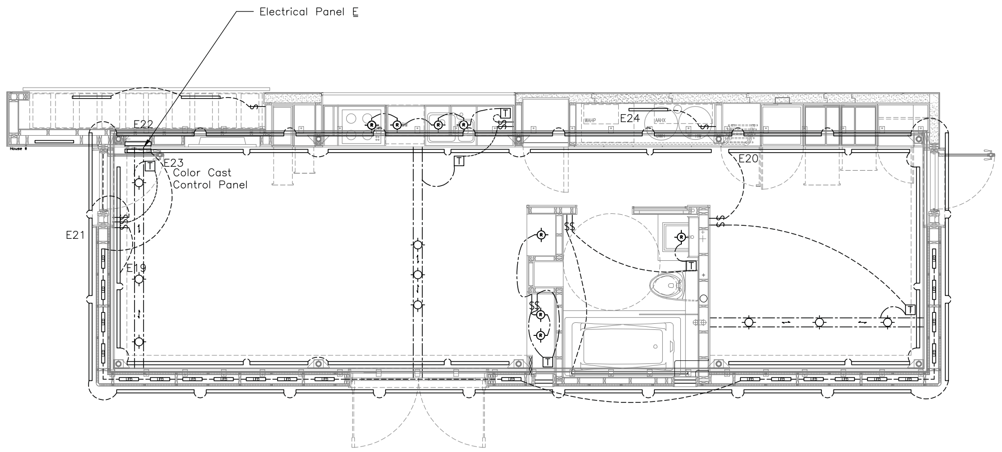
Note:

See Panel Board Schedule on sheet E4.0 for ckt designations

Electrical Symbols Library

Outlet
GFI Outlet
Floor Mounted Outlet
Quad Outlet
Junction Box
Linear Actuator For Wall Vent
Smoke Detector
Doorbell
Ventilation Fans
Ventilation Fan Switch
Cable TV Outlet
Ethernet Outlet
Telephone Outlet
Motor
Disconnect Switch

E / 1.0 FLOOR PLAN - POWER AND COMMUNICATIONS
SCALE: 1/4" = 1'-0"



Note:

– LED lights controlled in panel under ckt brkr box

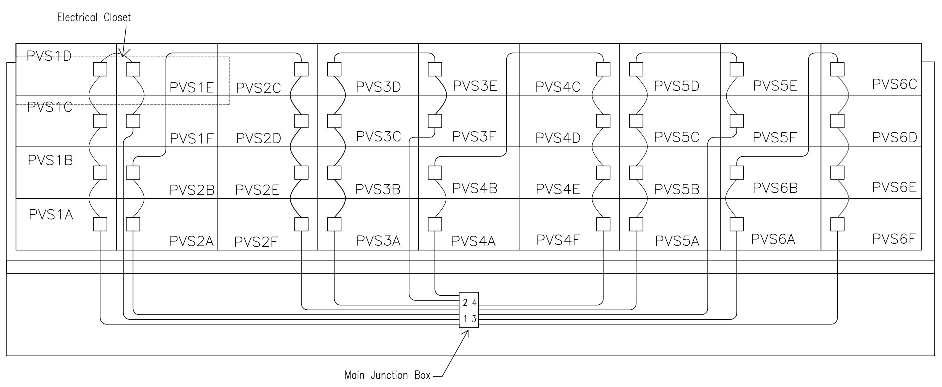
Electrical Symbols Library

Ceiling Fixed LT
Recessed Ceiling LT
Switch
Transformer for LV Lights

E / 2.0 FLOOR PLAN - LIGHTING
SCALE: 1/4" = 1'-0"

E2.0

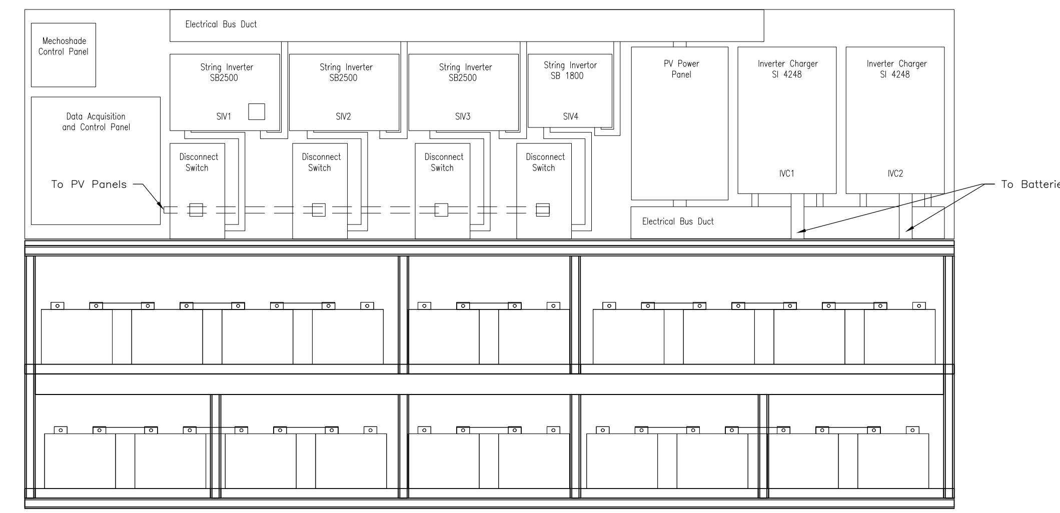
E3.0



E 3.0 ROOF PHOTOVOLTAIC PLAN

SCALE: 1/4" = 1'-0"

E5.0



E 5.0 ELECTRICAL ROOM ELEVATION

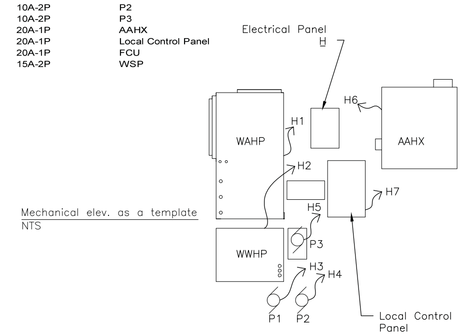
SCALE: 1" = 1'-0"

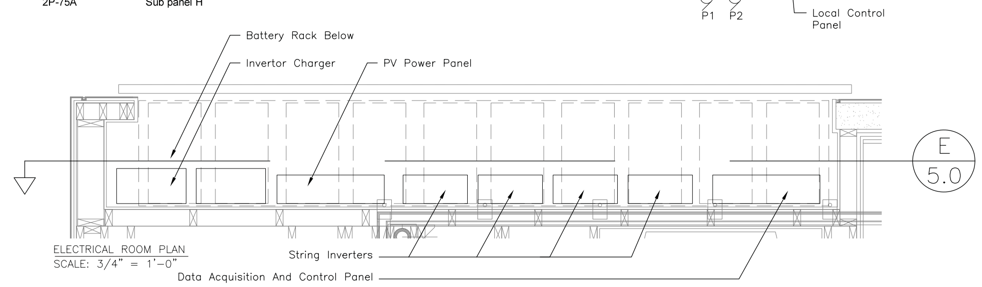
ELECTRICAL PANEL E
240 v / 1PH ; 100 A Main Breaker

CKT	SIZE	SERVICE
E1	1P-15A	LR Recept
E2	1P-15A	OFC Recept
E3	1P-15A	BR Recept
E4	1P-20A	Home Ent
E5	1P-15A	Kitchen-W Recept
E6	1P-15A	Kitchen-E Recept
E7	1P-15A	Range
E8	1P-15A	Microwave
E9	1P-20A	Electrical Rm
E10	1P-20A	Refrig
E11	1P-20A	Washer/Dryer
E12	1P-20A	Bathroom Recept
E13	1P-20A	Vent DprSV
E14	1P-20A	Ext Recept
E15	1P-20A	Electric Car
E16	1P-20A	Smoke Detector
E17	1P-20A	Vent Fan 1 VF-1
E18	1P-20A	Vent Fan 2 VF-2
E19	1P-20A	Int. Lightshelf - West
E20	1P-20A	Int. Lightshelf - East
E21	1P-20A	Ext. Lightshelf
E22	1P-20A	Int. Accent Lighting
E23	1P-20A	Color Cast Control Panel
E24	2P-75A	Sub panel H

ELECTRICAL PANEL H
240 v / 1PH ; 100 A Lugs Only

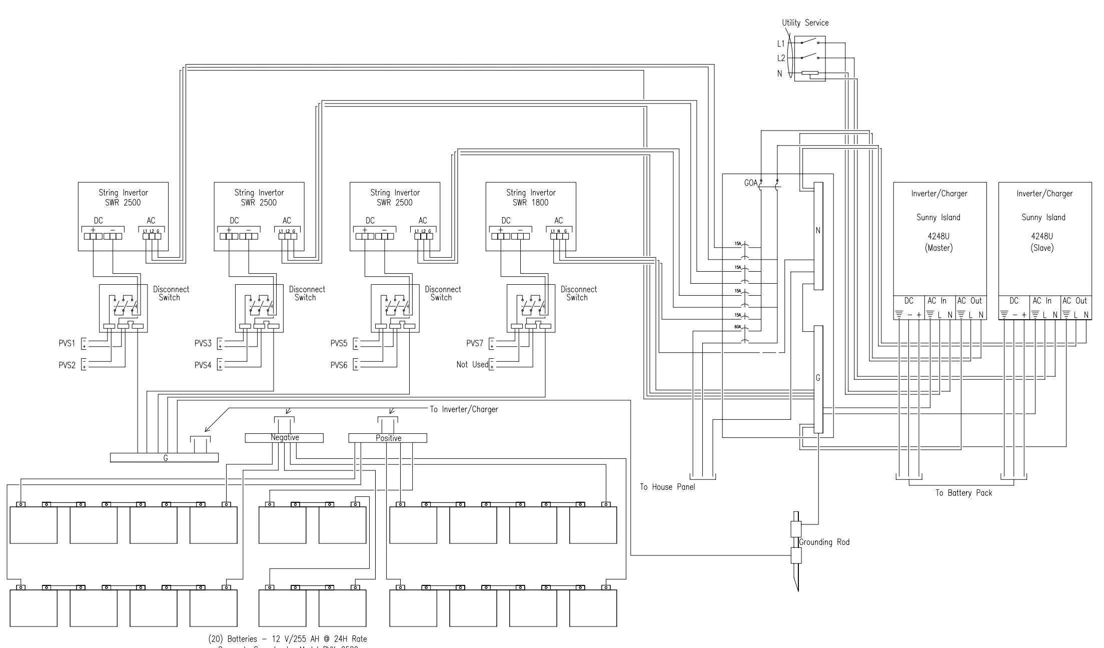
CKT	SIZE	SERVICE
H1	25A-2P	WAHP
H2	15A-2P	WWHP
H3	10A-2P	P1
H4	10A-2P	P2
H5	10A-2P	P3
H6	20A-1P	AAHX
H7	20A-1P	Local Control Panel
H8	20A-1P	FCU
H9	15A-2P	WSP





E 4.0 ELECTRICAL DETAILS AND PANEL SCHEDULING

NTS



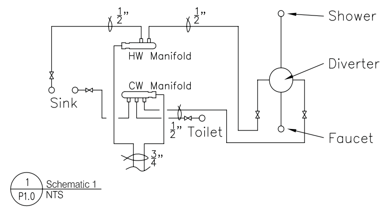
E 6.0 PV POWER SYSTEM WIRING SCHEMATIC

NTS

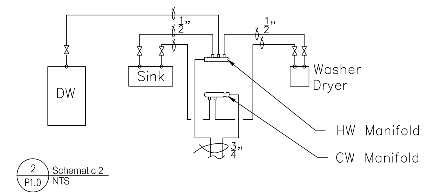
E4.0

E6.0

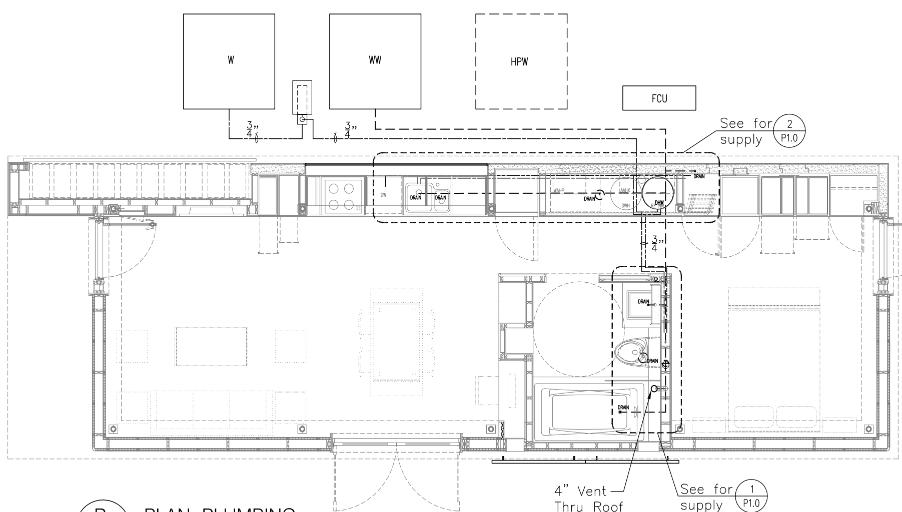
P1.0



1 P1.0 Schematic 1 NTS



2 P1.0 Schematic 2 NTS



Total Estimated Water Usage

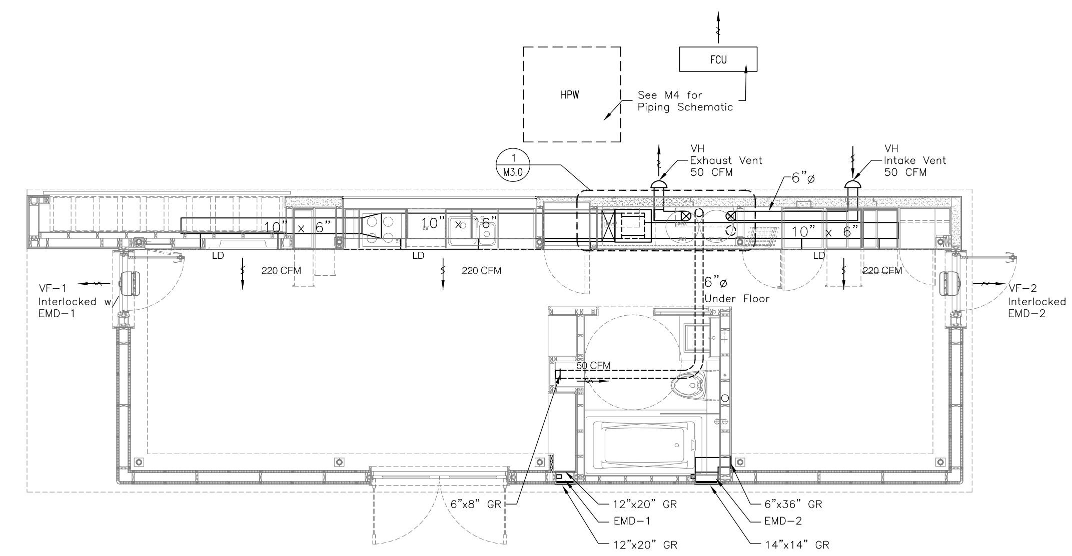
Freshwater Tank	260	gallon
HP System Tank	260	gallon
Hot Water Storage Tank	20	gallon
Radiant Floor Storage Tank	40	gallon
Landscape Tank	200	gallon
Cistern Tank	280	gallon
Piping & Misc	20	gallon
	1100	gallon

Legend

- Sanitary
- Domestic CW
- Domestic HW

P 1.0 PLAN -PLUMBING
SCALE: 1/4" = 1'-0"

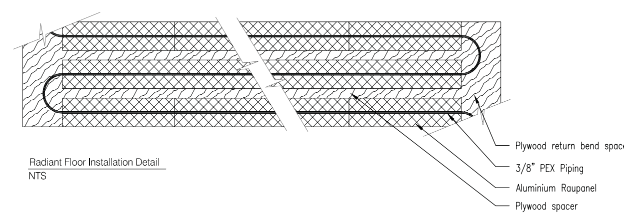
M1.0



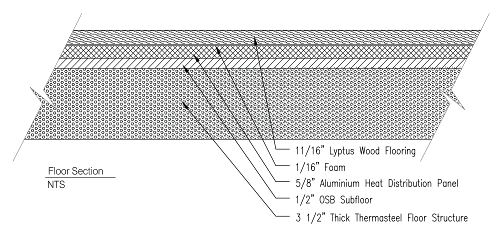
M 1.0 PLAN -HVAC
SCALE: 1/4" = 1'-0"

Air Distribution Specification

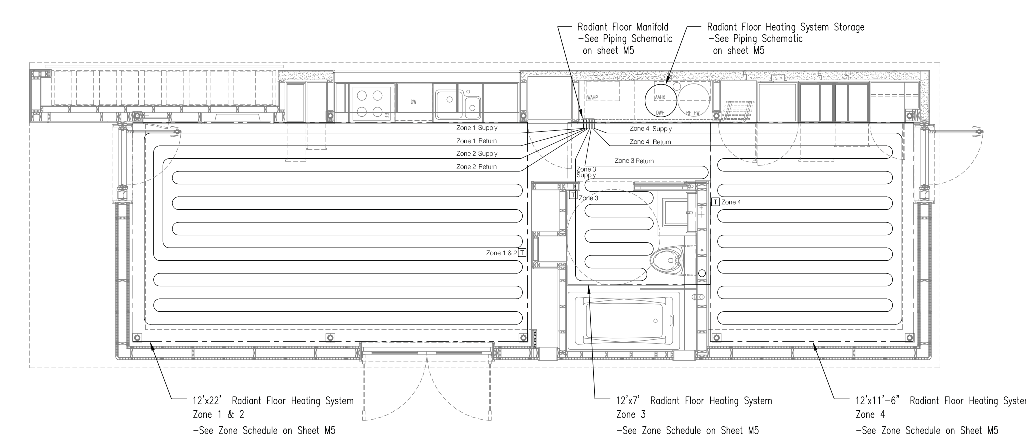
GR – Perforated grille ; Titus Model No. 8F
LD – 4'x1" Linear Diffuser (3) w/ 4' acitve sections, remaining sections blanked off; Titus Model No. FL10JT
VH – 7" dia. vent hood; Seiho Model No. SX-6
EMD – Electric Motorized Damper; Jackson Systems



Radiant Floor Installation Detail
NTS



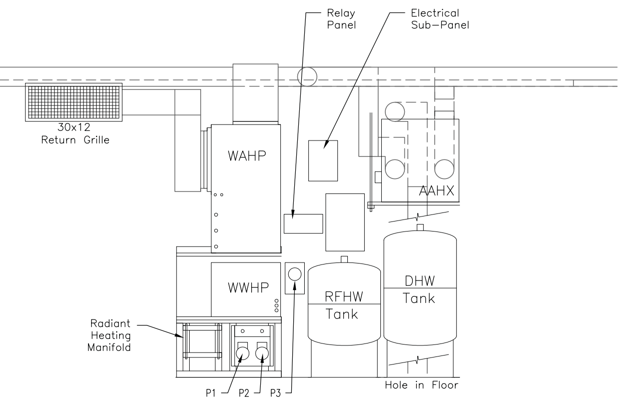
Floor Section
NTS



M 2.0 PLAN -RADIANT FLOOR HEATING SYSTEM
SCALE: 1/4" = 1'-0"

M2.0

M3.0



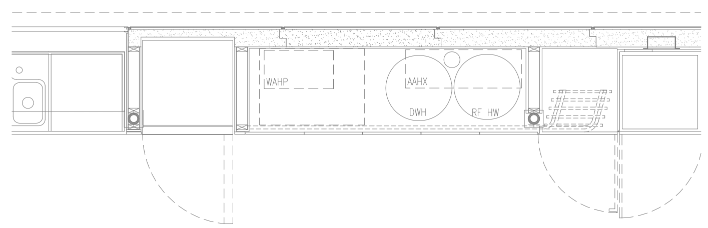
Equipment Notes:

WAHP
Water-to-air heat pump - FHP Model ES018
CLG Capacity = 17,200 BTUH CLG EER = 15.35
HTG Capacity = 19,000 BTUH HTG COP = 4.44
AirFlow Rate = 650 CFM at 0.40 IN. W.G.
Water Flow Rate = 4 GPM
Rated Conditions = 75FDB/63FWB/85FEWT for CLG
70FDB/50FEWT for HTG
Electrical = 17.5 MCA @ 240v/1 PH

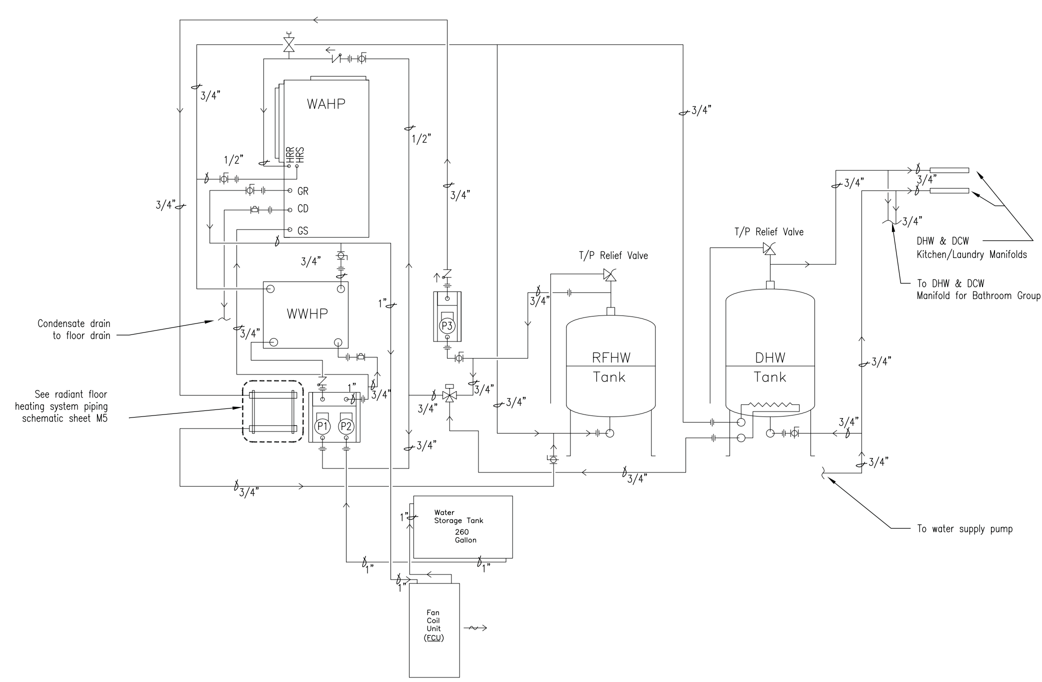
WWHP
Water-to-water heat pump - FHP Model WH018
HTG Capacity = 12,100 BTUH HTG COP = 3.6
Water Flow Rate = 3 GPM coldside 3 GPM hotside
Rated Conditioning = 65FEWT-Cold/120FEWT-Hot
Electrical = 9.5 MCA @ 240v/1 PH

RFHW
Radiant Floor Hot Water Storage Tank
Amtrol Boilermate Classic Model WH7
Volume 21 Gal

DHW
Domestic Hot Water Storage Tank
Amtrol Boilermate Classic Model WH-7-DW
Volume 40 Gal
Heat Exchanger - Double - Wall



M 3.0 MECHANICAL SECTIONS AND DETAILS
SCALE: 1/2" = 1'-0"



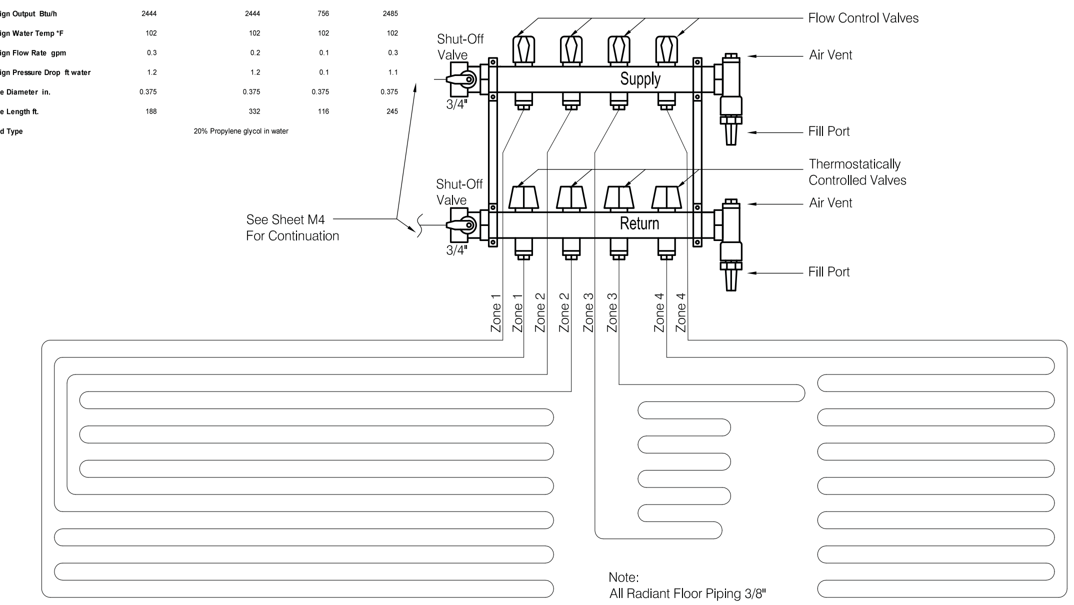
M 4.0 MECHANICAL ROOM PIPING SCHEMATIC
NTS

M4.0

M5.0

Distribution Zone Schedule

	1 Living Room Perimeter	2 Living Room Interior	3 Bathroom	4 Bedroom
Design Output Btu/h	2444	2444	756	2485
Design Water Temp *F	102	102	102	102
Design Flow Rate gpm	0.3	0.2	0.1	0.3
Design Pressure Drop ft water	1.2	1.2	0.1	1.1
Tube Diameter in.	0.375	0.375	0.375	0.375
Tube Length ft.	188	332	116	245
Fluid Type	20% Propylene glycol in water			



M 5.0 RADIANT FLOOR HEATING SYSTEM PIPING SCHEMATIC
NTS

Monitor/Control Wiring Table

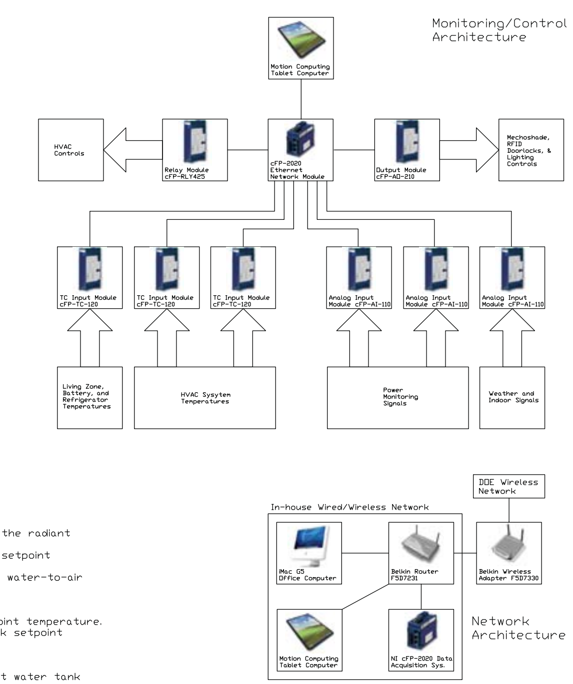
cFP Card #	Card Type	Application	Channel #	Terminal #	Monitor/Control Point
1	Analog Output	Mechoshade, RFID Doorlocks & Lighting Control	0	1	TBD
			1	2	TBD
			2	3	TBD
			3	4	TBD
			4	5	TBD
			5	6	TBD
			6	7	TBD
			7	8	TBD
2	Analog Input	Energy Monitoring	0	9	PV Current
			1	10	Main Panel 1
			2	11	Main Panel 2
			3	12	Battery Current
			4	13	Battery Charge
			5	14	Gem Vehicle Current
			6	15	Gem Vehicle Charge
			7	16	HVAC Current 1
3	Analog Input		0	17	HVAC Current 2
			1	18	Wtr Heater Current
			2	19	Dishwasher Current
			3	20	Stove Current
			4	21	WasherDryer Current
			5	22	Refrigerator Current
			6	23	-- Open --
			7	24	-- Open --
4	Analog Input	Weather Monitoring	0	25	Outdoor Temp
			1	26	Outdoor RH
			2	27	Wind Speed
			3	28	Wind Direction
			4	29	Barometric Pressure
			5	30	Solar Radiation
		Indoor Conditions Monitoring	6	31	Indoor RH
			7	32	-- Open --
5	Thermocouple		0	1	Living Zone Temp
			1	2	Bedroom Zone Temp
		Energy Monitoring	2	3	Refrigerator Temp
			3	4	Freezer Temp
			4	5	Battery Temp
			5	6	-- Open --
			6	7	-- Open --
			7	8	-- Open --
6	Thermocouple	HVAC Monitoring	0	9	Domestic HW Tank
			1	10	Radiant Fl HW Tank
			2	11	Radiant Floor Return
			3	12	WWHP In
			4	13	WWHP Out
			5	14	WAHP In
			6	15	WAHP Out
			7	16	Return Air
7	Thermocouple		0	17	Supply Air
			1	18	Condenser In
			2	19	Condenser Out
			3	20	Heat Reservoir Tank
			4	21	-- Open --
			5	22	-- Open --
			6	23	-- Open --
			7	24	-- Open --
8	Relay Output	HVAC Control	0	-	Radiant Floor Pump
			1	-	Heat Pump Heating
			2	-	Heat Pump Cooling
			3	-	Fan On/Off
			4	-	WWHP On/Off
			5	-	Reversing Valve
			6	-	-- Open --
			7	-	-- Open --

Sequence of Operations

Space Conditioning:
When space temperature falls below the setpoint deadband, start the radiant floor pump.
When space temperature falls to a predetermined value below the setpoint deadband, start forced air heating.
When space temperature rises above the setpoint deadband, start water-to-air heat pump in cooling mode.

Radiant Floor Tank:
When outdoor temperature falls, increase radiant floor tank setpoint temperature.
When radiant floor tank temperature falls below radiant floor tank setpoint deadband, start water-to-water heat pump (heating mode only).

Domestic Hot Water Tank
When domestic hot water tank temperature falls below domestic hot water tank setpoint, start water-to-water heat pump and energize control valve.



M 6.0 CONTROL SYSTEM SCHEMATIC
NTS

M6.0

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It's totally fine for you to use the photos. Please credit them as:

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Thanks, and best of luck on your thesis,
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Solar Decathlon's permission.  I will additionally site the Solar
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you have any additional requests.
Sincerely,
Brett Moss
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Special thanks to my family for their support and most importantly my wife Orianna who dealt with the absence of my presence for two years.

IN MEMORIAM:	SUZAN MOSS	MOTHER
	BEATRICE SHRENSKY	GRANDMOTHER
	JEROME SHRENSKY	GRANDFATHER
	DR. VASAR MOSS	GRANDFATHER
	MARY ANN STEIN	AUNT

THE DEVIL IS IN THE DETAILS The 2005 Virginia Tech Solar House

The relationship of the architectural details with the central architectural idea

Brett Greer Moss