A New Norris House: Give and Take

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INTRODUCTION

In 1933, by the passing of the TVA Act, the United States Congress created the Tennessee Valley Authority—the nation's first federally operated utility. Tasked with the goal of bringing the impoverished region out of the depression, the agency would address "a wide range of environmental, economic, and technological issues, including the delivery of low-cost electricity and the management of natural resources".[1] Shortly after its formation, the TVA began the Norris Waterworks Project. As part of the dam construction effort, the TVA also created a small model community to serve as worker housing. Built entirely anew, the town of Norris was designed around the principles of the Garden City movement and was envisioned as a self-sustaining utopian community.

A key feature of this New Deal Village was the Norris House, a series of homes built for modern, efficient, and sustainable living. Employing a large team of designers, engineers, and both skilled and unskilled laborers, the TVA experimented with new types of materials and delivery methods.[2] New technologies and prefabricated elements were quietly integrated into aesthetically pleasing, vernacularly-inspired homes, allowing residents to immediately identify with the new structures. However, despite their familiar aesthetic, the introduction of electricity and indoor plumbing revolutionized the way residents of the Tennessee Valley would dwell. The TVA's interest in exploring new building technologies, including prefabricated housing, would continue for many years, though the town of Norris and its iconic Norris Houses would stand as their most complete effort.[3]

In 2008, in light of the 75th anniversary of the Norris Project, a University of Tennessee – Knoxville team, led by the School of Architecture and Department of Planning, set out to reinterpret the Norris paradigm and create a New Norris House – a sustainable home designed to address the constraints and imperatives of the 21st century. As a 2009 winner of the US Environmental Protection Agency's People Prosperity and Planet (P3) Competition, the project team secured $75,000 in critical seed funding. A commitment from

Clayton Homes, the nation's largest manufactured and modular homebuilder, was also central to moving the project from concept to reality. This paper focuses on this collaboration – between an interdisciplinary university design / build team and a vertically-integrated industry partner; the completed New Norris House; and an in-progress post-occupancy evaluation period. The process and prototypical project reveal several key challenges – namely quality control and critical path sequences unique to the academic and industry partnership and to the process of and necessity for combining on- and off-site fabrication.

Relationship with Industry Partner

Over the past seven years, an evolving relationship between Clayton Homes and the UT College of Architecture and Design (CoAD) has yielded beneficial factory tours, guest lectures, and an [unrelated] collaborative housing design studio. The New Norris House project greatly expanded this relationship, as the academic project team pursued Clayton Homes to become a primary partner tasked with fabricating the modular portion of the home. The academic team was interested in this partnership for a variety of pedagogical and practical reasons. Clayton's effectiveness and streamlined process intrigued the team and offered much to be learned. Further, utilizing Clayton's manufacturing abilities greatly accelerated the project's delivery once construction began, in addition to giving the young design/build program increased credibility through the partnership.

In the fall of 2009 the academic project team was expanded to include structural and civil engineering, environmental studies, and architecture students. Functioning as an integrated team, the group developed the design of the home, while simultaneously working as "entrepreneurs" to secure partnership with Clayton Homes. This effort culminated with a presentation to Kevin Clayton and Keith Holdbrooks (Clayton Homes CEO and President of Manufacturing, respectfully) and the team's success in winning Clayton's confidence in the student team. Clayton not only agreed to provide both pre-production support and to build the modules at cost, but was excited by the project itself and by its customer's prospective interest in similar potential efforts by their own design team.

At the time of partnership in December of 2009, many open questions remained. Though the project had been brought through design development with the potential for modular fabrication in mind, marrying the design with Clayton's fabrication process proved to be challenging. Factory visits and coordination meetings with Clayton's design team revealed a process shaped entirely by efficiency. Though this came as no surprise, Clayton's optimized processes came to shape the progression of the work in unexpected ways. Prefabrication of the student design stretched Clayton in several respects and one-off production tested the capacity of their laborers to perform at levels (speed and quality) equal to that of their standard product. The specifics of these difficulties are explored here with respect to each major construction system.

Site and Foundation

The project team initially sought to utilize a pre-cast foundation. Factory-insulated foundation panels would be craned into place and set on top of site-cast footings. The prefabricated units would cut down site preparation time, save money, and eliminate the need to further insulate on-site. As coordination effort continued with Clayton to define the scope of work surrounding the delivery and installation of the modular units, several changes had to be made. Due to nearby homes, sloping terrain, surrounding vegetation, and utility lines, it became apparent that the use of a crane to set the foundation and the modular units was not viable. Most modular installations done by Clayton's team occur on greenfield sites, but in the case of the New Norris House there simply was not enough space to accommodate the necessary equipment and staging areas.

This realization would stand as one of several moments when the project's fate would hinge upon the team's ability to adapt, and had an immediate effect on the foundation type, modular delivery method, and timeline for completion. What had been envisioned as a series of pre-fabricated components was forced to a more typical path. Five project team members in the first semester of the construction participated in a multiple week masonry methods course, culminating with their laying of the building's foundation. While this took 1/3 of the students enrolled in the course away from other tasks, it presented an enormous opportunity to learn. As another consequence of the inability to use a crane, the foundation had to be built in stages to accommodate the delivery of the modular units on a chassis and roller system. (Figure 1) Coordinating deadlines with Clayton towards the modular delivery presented students a clear example of critical path coordination.

While the project team desired the use of the pre-fabricated system for a variety of reasons, the educational and experiential opportunities were a reasonable tradeoff for the time lost. While the process would be difficult to optimize further, the related issues arose primarily from the surrounding context of the site. The use of the roller system to set the home (referred to by Clayton's setting team as "old tools") enabled the use of the difficult site by trading advanced tools (a crane) for increased labor. Multiple, smaller units could have potentially enabled the use of the crane (less staging area and smaller crane required) in the tight, infill site. Also noted by setting team from Clayton, the temporary utilization of a neighboring property's driveway could have also allowed for setting of the units by crane. The importance of building relationships with neighbors is not to be understated (security, acceptance of project in community, etc).

Figure 1: The first modular unit is set onto rollers before being shifted laterally across the staged foundation wall.

Structure

Several initial structural changes had to be made which the project team also had very little control to modify. Historic dimensions of Norris homes drove the footprint of the New Norris House to 20x30 feet. However, as consequence of jig dimensions used to construct floor framing within the factory, the rough footprint of the home had to be enlarged to a 24' width (two 12' wide modules). While Clayton empathized with the desire to meet the historic dimensions, it was simply not feasible to modify the jig for a one-off production. Substantial capital investment or the production of multiple units could justify this modification, both of which were not available options to the project team. A max shipping width of 16 feet (regulated at the state level) and a minimum width that can be easily moved down the factory assembly line are the only limitations to this end. Future developments could potentially use multiple, smaller modules to achieve additional forms. The TVA itself experimented with this method, finding it to be advantageous to panelized or trailered systems in its ability break from a standard module and give the designer more freedom.[4]

Another design decision which originated in the context of the historical building stock was the pitch of the roof. Original homes built in 1933 have an archetypal, simple form and are characteristically built with gabled roofs. Efforts by the project team to use a continuous ridge beam with no collar ties complicated this matter as the design was adapted for modular production. Due to the height of the ridge, the roof system would have to be hinged for shipping. This is a process Clayton does regularly and was an easy translation. However, Clayton's standard approach includes collar ties and more structural walls. The largely open plan/volume, limited use of full height walls, and desire to limit the marriage wall to a single stud wall contributed further complications as Clayton was concerned for the structure's rigidity (walls and roof) during transit and, more importantly, hinging into place. Clayton was also concerned about cracking the finished drywall during erection of the hinged roof panels – as it had no experience with the large, unsupported roof spans and open, finished ceiling. Clayton's factory was also not equipped to use SIPS – a possible solution adding rigidity and avoiding the potential cracking the finish ceiling. The desired roof insulation rating (R-40+) coupled with the fact that the Clayton factory did not do foam-in or interior rigid insulation led to the solution as carried out on-site. Pre-cut and pre-hinged rafters were installed on each module in the factory, and raised to full height and secured once the modules were put in place. (Figure 2) This had implications for skylights, but few other rough-in services which were already held out of the ceiling for other reasons.

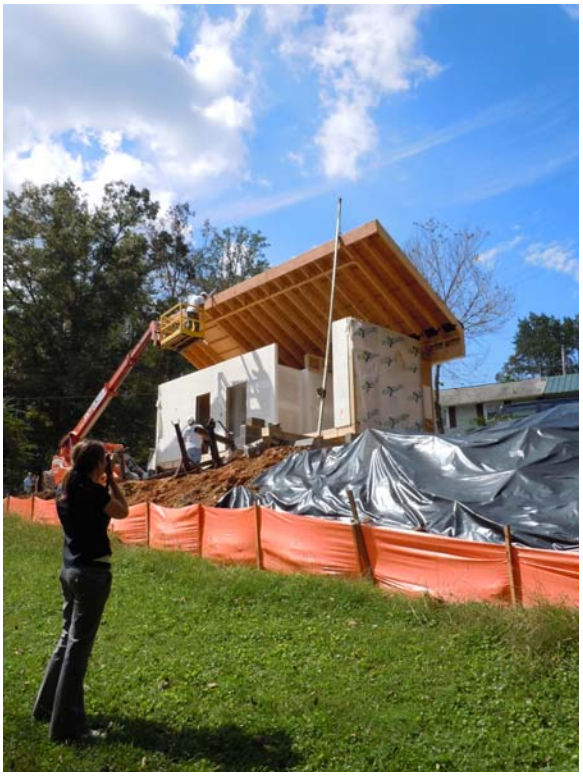

Figure 2: The roof of the first modular unit is hinged into place before temporary supports are installed.

Envelope

The envelope of the New Norris House is one of the clearest examples of on-site versus off-site layering. As the façade system developed, it was generally assumed that Clayton could not execute the vertical rain-screen siding in a manner consistent with their typical manufacturing process. There were simply too many pieces (300+ individual siding boards) to install the siding in a timely manner, while simultaneously maintaining a high degree of quality (square, level, consistent nailing patterns, equal spacing between boards, etc). Clayton's standard siding package is a vinyl exterior installed primarily in the factory, and completed on-site to cover endwalls and modular seams. While Clayton has the technical ability to install nearly any type of siding system, their preference for siding choice is driven by ease of installation to ensure quick product turnover and meeting ideal price points. While UT controlled the material budget, it was agreed that shifting the siding installation to the scope of on-site work would be most ideal.

As coordination progressed, the scope of the window and door installation was modified as well. Complicated details surrounding window flashing and creating a workpoint for the rain screen installation left both parties worried this could be done quickly or easily in the factory. Blocking for siding required the careful removal of rigid insulation around windows and doors, with flashing overlapping from the rough opening into this void—a time consuming task that was not feasible in the factory. (Figure 4) Furthermore, fixed windows, as well as interior and exterior doors were originally specified as off the shelf products, but high prices and a desire for more design control shifted fixed windows into UT's scope for custom design and fabrication. This decision created a timeline incompatible with Clayton's manufacturing schedule, thereby determining the installation of these components by UT.

The elimination of window, door, and siding installation left the exterior of the home as a clean shell (with the exception of the end wall gables, which were infilled with stud wall on-site as further consequence of the roof hinging sequence). (Figure 3) The two modules would receive exterior rigid insulation and building wrap from Clayton and then ship as unfinished boxes ready to receive custom exterior finishes. The process to finish the siding and window installation would prove to be the most time consuming task involved with the completion of the home (further justifying the inability to complete the siding as designed in the factory). The detail for the pre-stained, vertical siding pattern had little built-in tolerance, and thus easily revealed mistakes where elements of the modular shell were not perfectly plumb and square-- requiring a high degree of craft and patience to be installed correctly. A more tolerant or panelized system might have been detailed to allow Clayton's production team to execute the installation in a quick and forgiving manner. This could have involved the delivery (UT to Clayton factory) of pre-stained siding and pre-beveled horizontal furring strips, certainly plausible. As part of potential efforts to simplify the siding pattern, drainage planes around windows could have also been more optimized to reduce anxiety about proper execution in the factory. Custom, well crafted, and highly detailed components added greatly to the quality and learning experience of the student team in their efforts to both design and fabricate these elements. Students learned from direct experience the impact of seemingly simple details upon the sequence of work, labor time, and the methods and tools employed. As consequence, however, considerable time and effort was expended to reach this end.

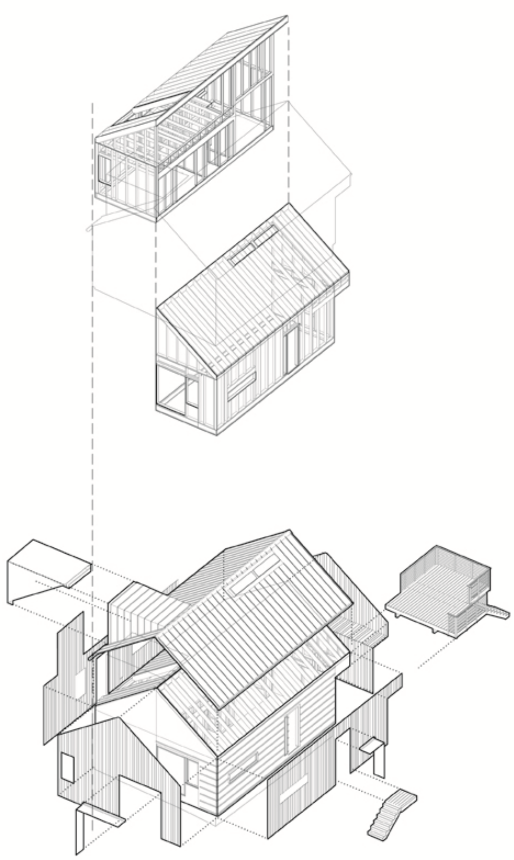

Figure 3: (Top) The design of the home is adapted to the manufacturing process. This process ensures high efficiency of materials use, quick "product" turnover, and a degree of accuracy which is not always possible in the field. (Bottom) Elements of the home were built or installed on-site-- such as windows, doors, siding, decks, steel canopies, and landscape elements.

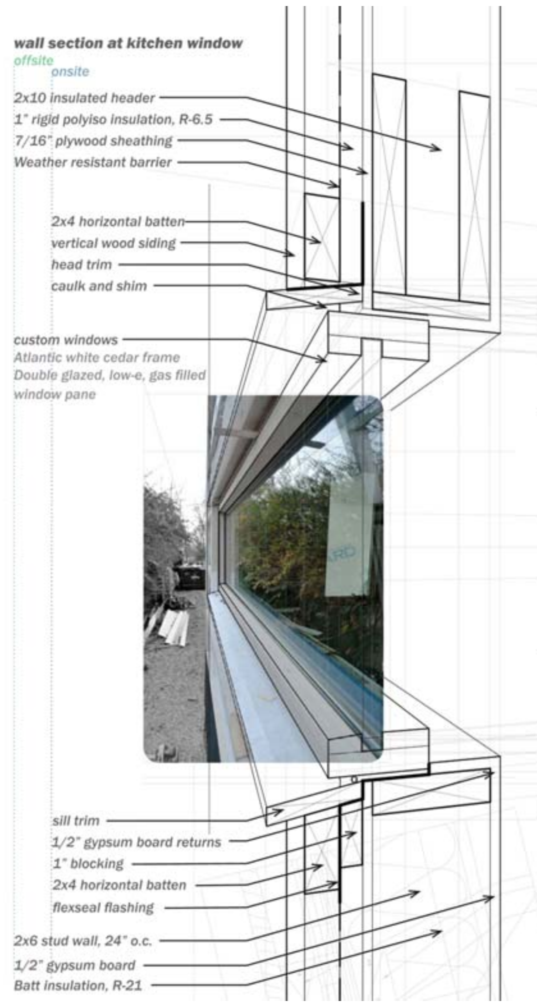

Figure 4: On-site vs. Off-site construction detail of a typical window section

Systems

Large efforts were put into the mechanical, electrical, and plumbing systems of the New Norris House to ensure optimal performance while fully integrating into the design of the home. Typically, Clayton ships homes with MEP packages completely in place (sans necessary external equipment and connections). However, as coordination progressed, the scope of work was slowly dialed back from Clayton's production facility and several small changes pushed MEP work further into the realm of on-site completion.

Utilizing a ductless mini-split heating and cooling system, interior blower units were carefully placed within integrated casework. Early interior studies to design casework and identify an ideal method of production considered Clayton's in-house cabinet building shop. However, as the production deadline approached, efforts to produce the casework were shifted in UT's scope of work-- thus eliminating the potential to pre-run refrigerant lines and mount the interior heating/cooling units. This shift also eliminated any potential to install kitchen appliances or plumbing fixtures. Electrical sizing was completed based on specified appliances at time of Clayton's production (Fall 2010) and lines were stubbed out in predetermined locations at that time. As the development of the kitchen continued (into Spring 2011), several financially costly change orders were necessary to satisfy modified electrical needs.

As further consequence to the hinging of the roof structure and panelized dormer to be installed on-site, the solar hot-water panel could not be placed by Clayton. Though the heat exchange unit could have potentially been installed in factory and required only basic plumbing proficiency, the installation required some knowledge of the system's operation and schematic functions. This is a prime example of a difficulty raised by the presence of multiple hands in the selection, detailing, installation, and commissioning of advanced MEP systems. The solar hot-water equipment was selected through contact with a regional product representative and rough plumbing was provided by Clayton in a manner specified by the academic project team. A local installer in conjunction with a plumbing sub-contractor completed the installation 6 months after Clayton's production. At nearly every turn difficulties arose, which largely could have been eliminated by bringing in the installer much earlier in the system selection and detailing process. The installer faced difficulties marrying the work that had already been completed with that of a system detailed and selected by another party. Efforts by the academic project team to use very small tolerances and work within a small footprint compounded these issues further. Similar problems arose with both the mechanical and electrical sub-contractors on-site, though not to the same degree. Though Clayton has utilized solar systems (electrical generation) in the past, deliberate efforts were made in this instance to seek a plug and play model with built-in inverters that required very little additional knowledge or skillsets. A similar, easy to install, off the shelf product related to solar hot water would be required to justify installation by Clayton at the time of production, or a market demand that supported the hiring of a specialist in the factory.

Conclusion

As the largest design/build project to date within the University of Tennessee's College of Architecture and Design, the New Norris House project constantly found itself facing challenges without precedent. Working with Clayton Homes, the project team benefitted greatly from their long history and expertise with prefabricated residential projects. By blending this process with that of traditional on-site construction, the project team was able to achieve several desirable ends.

First, as a building team made up primarily of inexperienced students, the project team would have been seriously challenged to dry-in the home by the end of the first academic semester had we not utilized Clayton's prefabricated modules. Not only did this help conceptually organize the effort into "rough construction" and "finish work" semesters, but it jump started the project and aided greatly in working around a five-week lull during the academic winter holidays (while the home largely sat untouched).

By eliminating specific components and elements from Clayton's scope of work, the project also benefited greatly from the additional time this allowed for continued design and development. As construction commenced, the academic project team was split between a host of tasks—generally related to on-site construction, and off-site development and fabrication within the college's facilities. Off-site work was thus permitted to occur simultaneous to on-site work, rather than being required to be complete before Clayton's fabrication in the fall of 2010. This also allowed the execution of critical details to remain in the students' scope (flashing around complex window assemblies, skylight and ceiling drywall, air sealing, and wall tile). While these tasks could have easily been completed in the factory, they were shifted in order to allow the academic team to retain responsibility to ensure that critical performative and aesthetic requirements were met.

Lastly, the hybridized approach greatly expanded the responsibilities of the academic team beyond that of the production of contract documents, and made possible the opportunity to engage 40 upper-year architecture and interior design students directly to the construction process. Though the home could have theoretically been built to utilize a much higher amount of pre-fabrication, a deliberate effort was made to ensure that these tasks would fall directly into the hands of eager and curious students. Students not only learned the physical tasks of construction, but most importantly the value of craft, communication, and respect—which all became apparent by the implications of change orders, the sequencing of tasks, and other realities of construction.

Systems installation on-site by sub-contractors proved to be one of the more difficult tasks and possessed less inherent benefits in splitting the scope of work between multiple parties (rough-in work that took place behind finished walls as a necessary exception). Though all groups involved (UT, Clayton, and sub-contracted installers) contributed technically sufficient and adept work, largely these difficulties could have been avoid by reducing the amount of contributors involved.

The potential of projects such as the New Norris House is wide ranging. Partnership with Clayton Homes enabled the investigation of many ends which would otherwise be left unexplored or underutilized using a traditional on-site construction method. The give-take nature of the relationship between on- and off-site construction has few black and white answers. Though the multi-faceted approach to the project's delivery increased time invested at many phases, the outcome provided the best of many singular approaches. A healthy respect between the two delivery methods and the processes which shape them helped marry the two methodologies, and the nature of the academic and industry partnership provided opportunities for all parties involved to stretch their thinking and abilities.

Figure 5: A New Norris House (photo by Ken McCown)

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Endnotes

1. "From the New Deal to a New Century." The Tennessee Valley Authority. http://www.tva.com/abouttva/history.htm. July 6 2012. (accessed July 6, 2012).

2. Avigail Sachs and Tricia Stuth. "Lessons from the Past: A Tennessee House for the Future." *Journal of Construction History* Special Issue on the Americas (2012).

Publication under final review. Provides an in depth investigation of the TVA's early experiments in residential construction technology.

3. Ibid.

4. Ibid.