Building Capacity

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Contemporary reconsideration of the relationship between design practice and the act of making has primarily been influenced by two not unrelated technological and operational developments. On one hand, the emergence of digital tools has had a resultant impact on the immediacy of the critical path between conception and execution of built work. On the other hand, there has been a development of modes of practice in which designers embrace the professional terrain of the maker, eliminating the contractual distance between design and the execution of a given artifact. This paper presents a recent immersive research-design-build project undertaken at the University of Waterloo within the graduate MArch program, where both the relationships between design and making defined by craft-based skill sets, and the formal cycles of iterative design typically defined by disciplinary project phases were opened for redefinition throughout the project duration. This was achieved via the integration of interdisciplinary research activity running concurrent to design work, and the extension of design refinement throughout the build process. Partnership with industry and professional fabricators positioned student team members not as builders per se – but within a unique context of advanced design-build collaboration.

NORTH HOUSE

The *North House* is a funded design-research project[2] to develop a high-performance, responsive, net energy producing prototype house specifically designed for northern climate conditions, as well as to question the ways in which architectural design can foster new forms of sustainable living. The project was selected as one of twenty finalists in the US Department of Energy's 2009 Solar decathlon, and is a collaboration by the University of Waterloo, Ryerson University and Simon Fraser University. Within the University of Waterloo's Graduate Architecture Program, the proje ct has been utilized as a catalyst to develop modes of studio and non-studio based education that have positioned architecture student participants as design team collaborators in the context of an interdisciplinary office model over the course of an eighteen month period. Due to the unique structure of the graduate program at the University of Waterloo, and the circumstances surrounding the positioning of this work, students participated throughout all phases of project development, and most were fully supported through grants to develop the project throughout its 18 month duration, undertaking rigorous cycles of research and simulation, BIM modeling, systems coordination, prototyping, detailed design refinement, contract document production, fabrication prototyping with industry partners, hands-on training with licensed trades, manufacturing, field review, contract procurement and shipping logistics. In short, the students were intensely involved in developing a design and construction project through all exigencies of the full project cycle.

What is perhaps more interesting than the breadth of this training is the conditions of collaboration in which it occurred. Throughout the project, student team members worked with a variety of disciplinary experts, embedded extra-disciplinary student colleagues, industry partner collaborators, and software developers and programmers throughout all phases of the work. The flexibility, exposure and control of this mode of operation not only provided an invaluable education and training opportunity, but anticipates the transformation of professional capacity with deep-knowledge and working process skills acquisition. This new will undoubtedly be a factor driving professional practice models within the arena of high performance integrated systems building design necessary to deliver advanced net energy producing buildings. That this work is undertaken directly within the architectural design studio work has been essential for its integration with project conception, design, and development. It has also served to emphasize, for students involved, the essential connection between conception and execution, design and detailing, research and making, creativity and precision.

WORKING PAST THE MYTH OF AUTHORSHIP

The Integrated Design Process (IDP) that is recommended by current sustainable design methodologies[3] formed the basis for the project's initiation and the determination of its design and performance objectives. This model is intended to ensure that across each major design decision within a project, an inclusive set of disciplinary voices are brought to bear on the project's direction. At the project's outset, student team members from Architecture, Mechanical, Civil, Electrical, Mechatronics, Systems, and Software Engineering met with leading researchers and professional colleagues form a team and to define the primary project objectives. Criteria for design and performance were defined by an overarching set of principles and objectives that were developed with the team during a three-day workshop (Figure 1, above). In order to develop objectives relevant and appropriate to the expertise of the team, the workshop first defined the leading edge of respective participant's disciplinary perspectives, and then set out to describe a synthetic approach to project development that would position these objectives as both the drivers of design, performance, and systems criteria that would remain across the course of project development. Successful consensus-building and group buy-in to these objectives is one of the factors that has guided all subsequent project decisions across the eighteen month duration from conception to completion.

The objectives developed at the outset of the North House project were: (i) A *strategy* of construction and space-making for Northern Climate Extremes, capable of adaptation to regional and cultural differentiation; (ii) DReSS: Distributed Responsive System of Skins that combines active and passive technologies to result in a net-energy producing building design; (iii) ALIS: Adaptive Living Interface System, that combines a customized set of advanced controls with direct and ambient feedback systems intended to enhance and mediate individuals' relationships to the complex technologies and systems of the home, while fostering behavioral reinforcement of sustainable forms of occupation; and (iv) Holistic Solar Living: an ambition to develop and expand the potentials of the inhabitants' relationship to solar resources to be inclusive of a broad set of lifestyle enhancements, such as localized personal food production, daylighting opportunities, and robust links between interior and exterior environments[4].

As a result of this design process framework, each team member, and each team decision was governed by a set of interrelated and linked concerns marrying performance and aesthetic considerations. Project form and materiality become a matter of intensive conversations and performance considerations that drove form finding and decision making. Each discipline helped to shape the final form, and within the team, it was rapidly understood that each iterative inflection from the original diagram of spatialized systems was authored by the team, and the responsibility of the whole group. No single decision was able to be addressed independent of performance, and so – although lengthy, conversations regarding the merit of each inflection directed the work. Detailing, of course, was weighed equally relative to from, specifications were considered relative to intent. This method is a considerable departure from traditional, or even contemporary studio teaching, where the feedback and balance of such complex parameters for decision and form making is often not able to be explored.

The primary objectives developed during the initial workshop were not only to be valuable through-

Figure1: Collaborative design environments across cycles of design and making; (above) Student and faculty team discuss overarching principles during initial project workshop; (below left) Architecture and engineering students do working drawings in the project room at the University of Waterloo; (below, middle, right) Students working on site

out project development, but also proved essential in clearly communicating the potential sponsors, donors and granting agencies. As part of the curricular integration initiative, undergraduate architecture students developed and produced short videos that took each of the objectives as a point of departure to explain the emerging design. The videos became an invaluable tool for communicating the project both to a broader public, as well as to members of the team, who might be focused on other areas of development.

STRUCTURING ADVANCEMENT TEAMS

In order to provide structure and locus for the work, a primary project room was procured at the University of Waterloo with proximity to networked devices and the fabrication shop (Figure 1, below left). The 'project room' was understood to be different from the 'studio' insofar as the tone of activity was immediately more explicitly professional than one would expect than in the social/work space of the studio. Regular and revolving meetings took place in the center of the space, bringing professional peers, team collaborators, project to the wider public – including into the core of research work and design production. Despite the fact that team members were in some instances physically separated across the various locations of the collaborating institutions, the importance of a single physical locus for design refinement was critical. The state of the union could always be tracked in the project room, and for those working within this space, professional eavesdropping and informal discussions became the primary mode of tracking design evolution. The format of project critique familiar to the design studio model, with specific emphasis on actions, follow-up activities or the suggestion of lateral or parallel probes in the work was utilized on regular cycles in focused team groups to advance materials research, energy modeling, and design advancement. Design decisions, and material evaluations were undertaken within these contexts, with students presenting proposals for concentrated review with design faculty and team members from other disciplines in order to ensure that a full spectrum of concerns were considered at each junction. Visiting professional engineers, industry partners, and manufacturer's representatives were also scheduled to feedback on the project, its detailing, and assemblies during these sessions.

An early team visit to the Toyota Motor Corporation production facilities in Cambridge, Ontario (intended to foster appreciation of Mass-Customization or Delayed Differentiation techniques within the

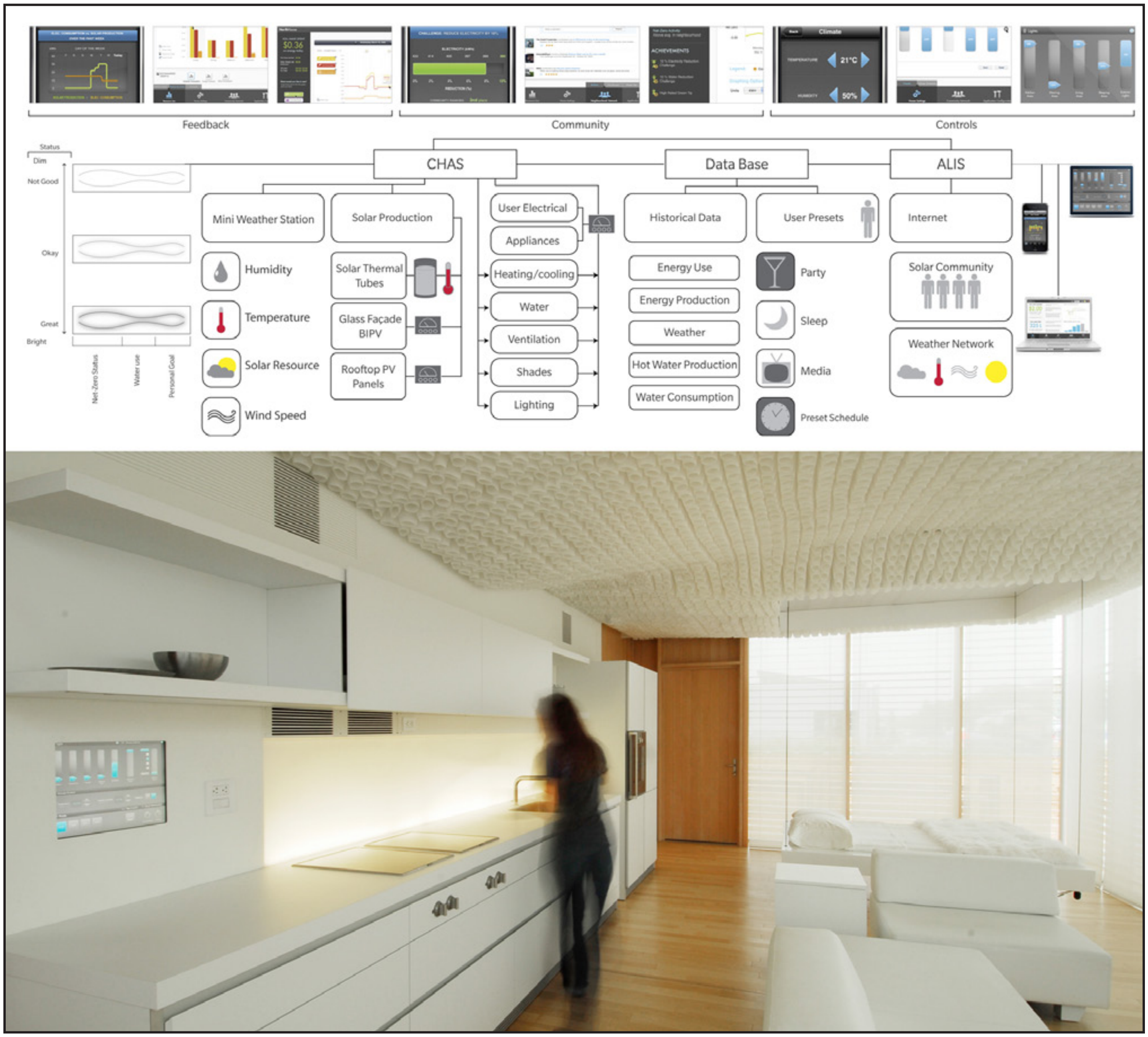

Figure 2: (above) Adaptive Living Interface System (ALIS) programming logistics, interior environments, interactive and ambient controls; (below) ALIS integrated into the North House interior environment

project projected modes of fabrication) introduced the concept of "Kaizen" – or continuous team performance improvement through the incremental implementation of all team member's initiatives to improve process and product. Kaizen became a slogan emblazed across the project room wall, and an active model of work for the team. Working model learning was not only gained by the students, but also by the faculty and professional collaborators involved. For example, the students' internalization of distributed social networking systems was legible, and constantly offered more senior team members a window into team organizational logics beyond those of our own experience - we would often witness several remote team members collaborating within compressed timeframes toward specific material solutions with virtual tools, yet still capable of maintaining constant informal contact as would those working in close physical proximity.

EXPANDING DISCIPLINARY BOUNDARIES

In order to manage the complexities of the project, specific project component teams were developed

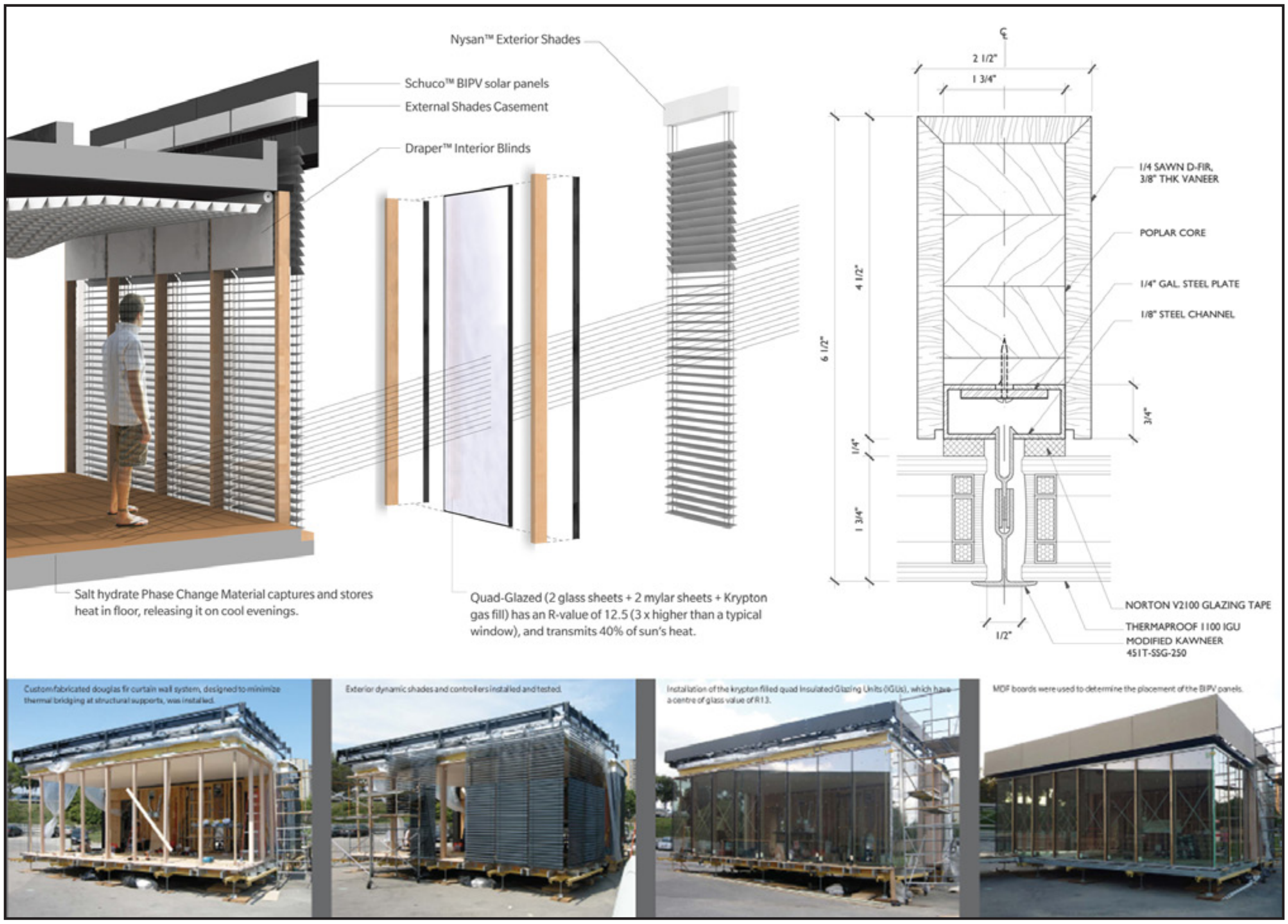

Figure 3: (above, right) Responsive Envelope System components; (above, left) Highly insulated wood curtainwall mullion detail; (below) responsive shading and glazing system during assembly

to bring to bear a range of disciplinary perspective on particular aspects of the project. These included teams that focused on glazing and active shading envelopes, structural assembly chassis and details, BIPV integration, HVAC systems, controls and sensor systems. However, each team was required to interface simultaneously with each interrelated team and system so that all components could be successfully integrated and so that incompatibilities and conflicts could be minimized in the built and operational prototype. While this methodology produced lengthy cycles of discussion during design development and detailing, especially since this was all part of a learning environment, the resolution and thorough troubleshooting undertaken during the design phase of the work radically reduced conflicts during the fabrication and assembly phases.

Of particular interest, was the development of the complex automated controls and human-digital interface systems of the project. Architectural students and faculty found themselves consulting on the development of controls software and interface systems. This student team consisting of graduate students from the architecture program, the school of interactive arts and technology, mechanical and systems engineering, computer science and sustainable systems programs worked through an intensely collaborative process to develop advanced controls systems with a digital graphic user interface, web, and smart phone application. While this work was coordinated and executed in partnership with industry partners Vertech Solutions and Embedia Controls, it was interesting to note the former work experience that was brought to bear by student team members including mature students, a retired project manager from Research in Motion (RIM), and a student who had directed product development within the biomechanical industry. Project development sessions for this aspect of the work, benefitted from the climate of the 'design studio' discursive critique approach, although much of the discussion, consisting of advanced computing and electrical engineering design logistics. The architecture students found themselves being educated in engineering and computing discourses and had to learn to navigate through design discussions that typically do not occur within our school of architecture. It is hoped that this type of collaboration might become more common in architectural design programs, as sustainable and high performance architecture increasingly embraces advanced technologies and automated systems.

The Adaptive Living Interface System (ALIS) developed by the team responds to the project ambition of enabling occupants to relate to the suite of advanced technologies and mechanical systems that govern the performance of the house. This is achieved primarily through the architectural integration of ubiquitous computing technologies that provide feedback and ambient cues when user-activated changes affect energy performance-prioritized presets. The three components of the ALIS system consist of: building integrated touchscreen displays for setting of user preferences and automated systems; an iPhone application that provides statistical feedback on energy and water use related to costs, as well as links to online communities to foster further sustainable lifestyle patterns; and a pattern of solid state lighting integrated into one of the interior building surfaces that provides ambient and 'atmosphere' and 'effect' are one of the recurring discourses in contemporary architecture, the direct collaboration with systems engineers, interactivity designers and building controls has been a uniquely valuable experience for all involved and significantly transformed the resultant space of the house. (Figure 2, below)

The development of the building envelope, while perhaps more familiar to design studio discussions, similarly introduced a broad range of technical and aesthetic variables into discussions that prioritized the design synthesis as a project goal. The goal of developing a 'responsive envelope' (Figure 3) as one that could mediate changing environmental conditions, rather than providing a static response to anticipated conditions, became a major focus within the subtle feedback on energy and water use.[5] (figure 2, above) Although discussions of design development discussions. Early energy modeling had made the case for large areas of high performance glazing coupled with active shading systems that could support passive heat gain to phase change materials (salt hydrate packets) embedded within the interior assemblies of the building. The process of selecting individual IGU elements (quad glazing utilizing mylar films with selective UV coatings was eventually deployed), coating for each face of this system, individual glazing tape types, spacer bar materials, mullion spacing and the like went through a rigorous process of digitally modeling each system and element configuration to evaluate its implications within the overall envelope system. The final configuration of mullion spacing, wood curtainwall cross sections, fastener-less ABS glazing caps, exterior venetian blinds and interior shades were determined within a complex matrix of dimensional logics, performance evaluation, and proportional concerns. The resulting system has been designed to outperform anything currently available commercially within the local market. (Figure 2, above)

Digital tools were utilized to not only anticipate and evaluate energy and thermal performance of this system, but to evaluate carefully the appearance of these systems. Student teams undertook energy modeling, three-dimensional digital modeling and visualization activities in parallel constantly tracking the implications of performance with respect to appearance, and daylighting levels.

These two initiatives, the ALIS system and the window system, are currently being described for patent applications that will list each of the student team members. The development of advanced high performance patentable systems, while familiar territory within parallel academic disciplines, is an emerging frontier with respect to design studio education.

RECONCEIVING THE LIMITS OF DESIGN/BUILD

Across North American schools of Architecture, many initiatives are underway that prioritize new relationships between thinking and making – design and production as a means to transform the

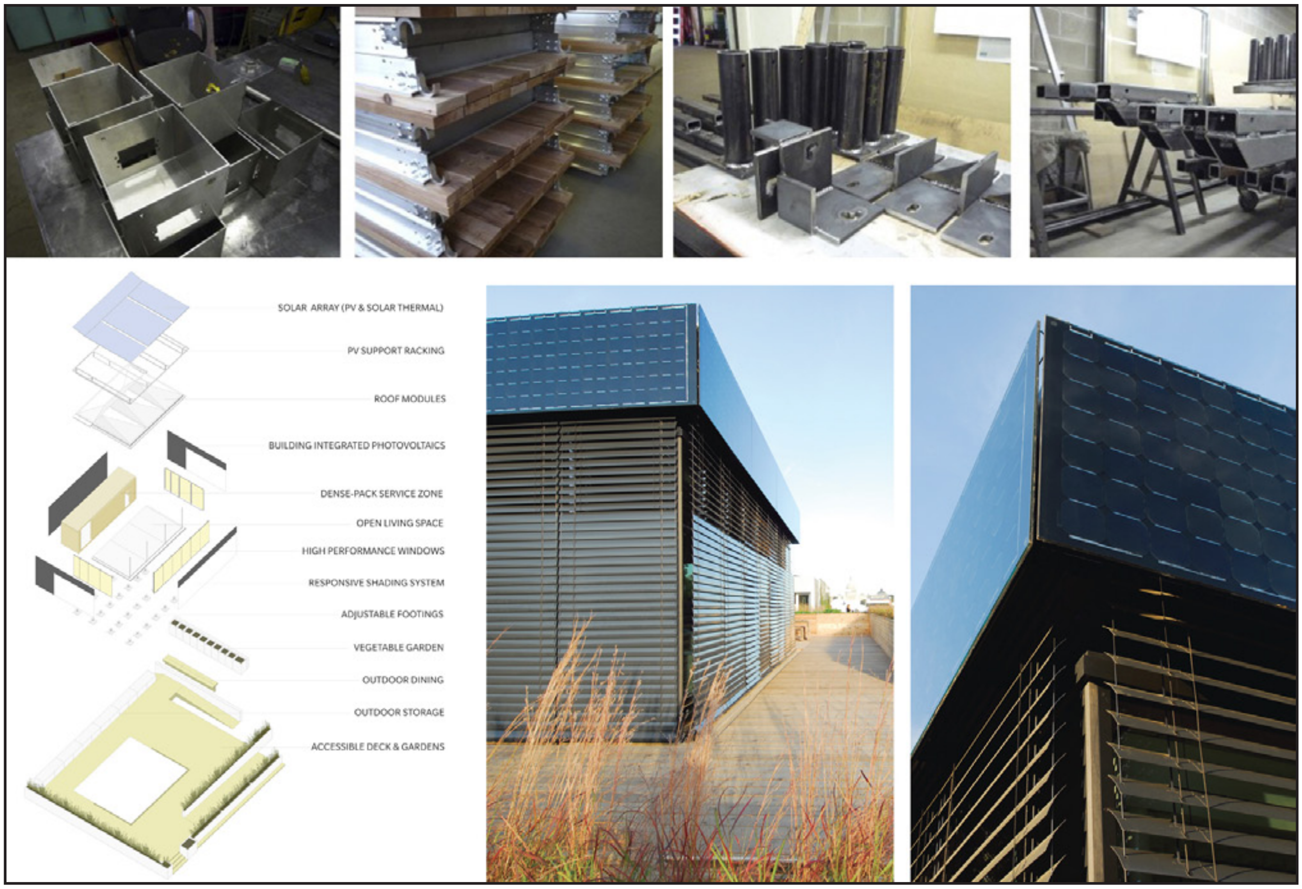

Figure 4: (above) Kit of Parts Logistics: building component elements during fabrication; (below, left) assembly axono-

role of studio teaching in the education of an architect. Within the North House Project, it has been the synthetic approach to the implementation of collaborative structures and ways of working that has been of the most profound impact. This is perhaps most evident in the several ways in which students' relationship to making and building itself have been cultivated. Rather than the prioritization of one method over another, the project embraces several modes in parallel, as appropriate to student skill sets, available resources and quality objectives.

Student team members prepared 1:1 physical mock-ups of all material assemblies during design development of the work, to the point where the technical skills of the team limited the capacity to test actual fabrication techniques. At this moment, collaboration began directly in the factory facilities of MCM 2001 Inc, the primary project fabricator, at which point students were embedded in the premises of the professional shop context. Here they developed familiarity with advanced CAD/CAM manufacturing equipment, as well as skilled trades techniques such as those of the machinist, break-former, the millworker, finish applicators. Working in parallel with a project manager from the company, students were directly involved in the 'shop drawings' process, so that their insights could be brought to bear on the discussions around fabrication logistics and sequencing, material limitations, and production efficiencies. There are those that might argue that this is not the realm of the designer, but for students working on the project, the uptake rate of these lessons was astonishing. Significant evidence of this learning was present in the transformation of the quality and precision of working drawings and prototypes produced by the student team, that consistently improved during the 12 week cycle of prototyping and fabrication that preceding building assembly.

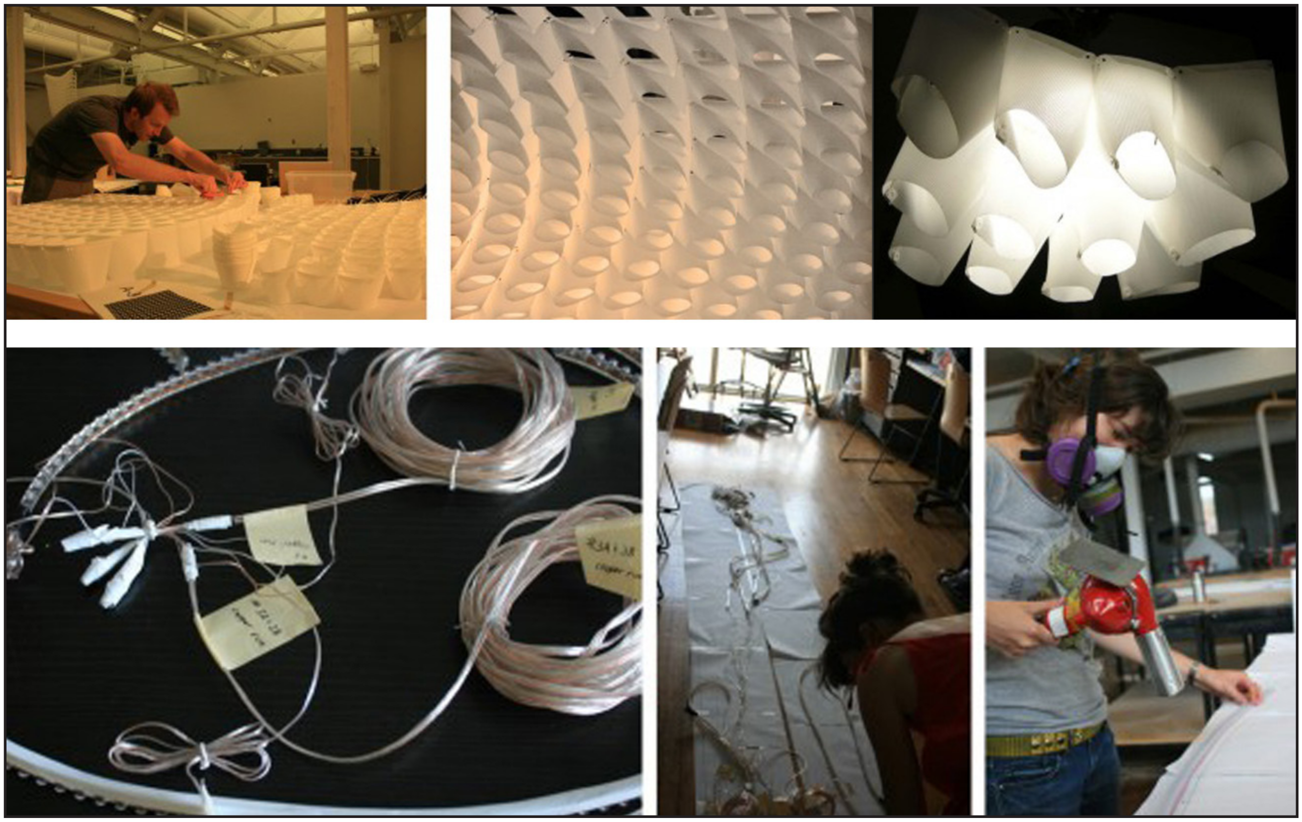

Figure 5: (above) Assembling fabricated diffusing ceiling assembly; (below) Solid state lighting formwork and installation.

Primary building components such as structural framing, cladding, and curtainwall systems were each developed though this process, as were the highly customized and materially unique interior storage systems, custom lighting fixtures, acoustic veneered ceiling paneling, and tension based descending bed systems. The rigors of industrial product manufacturing were applied to as many of the projects systems as possible.

During construction of the prototype, student team members again were embedded at the factory where each component of the project was produced on the shop floor, fitted, tested and finished prior to being assembled on the prototype proper, an activity which also occurred on the site of the professional fabrication shop. Contrary to traditional models of project document production and procurement, detailed drawings were produced in advance, during and after production. Each component of the construction went through several cycles of development, first informed by the inclusion of energy performance and digital modeling integration, then by the exigencies of the fabrication process and material realities.

The North House design combines both modular prefabrication techniques with panelized (or flat-pack systems), so that the final prototype is but one of multiple variations of spatial product (or building design) that is possible through the deployment of the system. Although the project ambitions to anticipate mass-customization were a major consideration in its organizational systemic design, the prototype production was much more similar to that of a 'concept car' prior to introduction of industrial production processes.

Within the primary service zone module, which we call the densepack, all services, HVAC, and systems components are concentrated. Contrary to the dispersed production of panelized and layered components in the factory, the densepack construction took place in the factory yard and involved extensive periods of systems fit-out, coordination and systems balancing. Here, the advanced nature of this installation, and the production of numerous custom HVAC components, again necessitated the primary role of professional tradespeople and fabricators. As a means to continue to keep students close to the content of design realization, students were paired with individual experts, operating as a form of apprentice, to facilitate both hands on learning and skills transfer, but also to cultivate the development of tacit knowledge of the complex set of operations, logistics, limitations, and dimensional realities that are implied by the design or technical drawing relative to the implementation of a given design instruction in the field.

The group of students working to develop the project's interior cellular fabric diffusing ceiling engaged the mode of production more common within digital-fabrication studios, by virtue of taking on not only a primary role in design activity, but also becoming its primary fabricators. Detailed material sourcing for this work sought to balance technical requirements for flamespread and carbon-neutral material embodiment, with the sensorial potentials of luminous presence. Student expertise in parametric modeling of the cellular system was complimented by manufacturing consultation for bulk laser cutting services. Preliminary experimentation into the technique of joining individual cells through stitching were evolved in consultation with representatives from 3M's advanced adhesives division to pursue transparent solutions to issues of joinery (Figure 5, above). In the end, however, it was the tradition of the 'quilting-bee', made possible through the long term friendships and communities fostered within design studio, that enabled the final hand-based crafting and aggregation of the over 4500 individual and unique cells that comprise the ceiling.

LEADING EDGE SKILLS TRANSFER

The experiment of North House, in terms of its success as a example of advanced design research driving both technological innovation, and design excellence, has been recognized by a range of awards, agency support and dissemination formats[6].

From the perspective of design education transformation and the goal of building new capacities and skills within the context of the studio environment, the project has sought to avail a multiplicity of opportunities for design students to learn both through iterative making and professional collaboration, and for this exposure to inform design as well as the construction of full scale building prototypes. Several unique organization conditions have structured a perception of how teams might work to advance a design in a multidisciplinary context and underscore the belief that each agent shaping a project's evolution is fundamentally participating in design activity. An interdisciplinary focus was prioritized both between student colleagues, but also with respect to industry and manufacturing partner participation.

The engagement of digital tools to develop material and environmental simulation, project visualization, and fabrication models were utilized and deployed alongside detailed physical prototype production, iteration and testing.

Deep research to test the performance, appearance, material reality and environmental impacts of material assemblies and proposals were integrated into the development of each design decision. New forms of drawing and prototype development drew from a range of ways to approach making. Student team members had to act and learn in a variety of situations outside both that of the traditional design-build studio, but also outside those that are engaged within traditional professional practice. For students engaged in this project, and the process of its design and making, the rewards are already legible - not only through an expansion of their individual skills sets, and the enhancement of their personal capacity to approach complex design problems in a dynamic team-based context, but also with respect to active professional recruitment.

It would seem that the challenges of developing high performance sustainable buildings in the future, that have the capacity to push beyond known methods of project design and making, demand a reconsideration of current practices and models of practice. As educators, we must consider the possibility of undertaking experiments with our students that question existing models and modes of operation in the context of collective learning, and in the primary domain of design education – the design studio. In doing so, we may find that the traditional form of design studio education might shed some of its preconceptions and prejudices and promiscuously absorb from a range of other disciplinary influences, models of structural organization, and enhanced connections to broader cultures of production and making.

ENDNOTES

1. All drawings and photographs courtesy of Team North. For a full project and team description, please visit www.team-north.com
2. Seed funding for the project was received from the US DOE / NREL, however, these funds were enhanced through MITACS/Accelerate Ontario, The Ontario Power Authority, NRCan, and The University of Waterloo. Over 80 students from three institutions participated in the project, with 13 full-time Architecture graduate students receiving full time funding for their involvement in the project.
3. For a discussion of the IDP process and intent, see Busby Perkins + Will, Stantec Consulting, "Roadmap to the Integrated Design Process. Part 1: Summary Guide," Developed for the BC Green Building Roundtable, 2007
4. For an extended discussion of the principles of holistic solar, see Velikov and Thün, "Contemporary Critical Regionalism and the Emerging North" 2008 Conference Proceedings of the Society for the Study of Architecture in Canada, and Velikov and Thün, "Complex Collaboration as a Lever for Design Research Innovation" Deep Matters: 2008 AIA/ACSA Teacher's Seminar: Cranbrook Academy of Art, Bloomfield Hills, MI (online proceedings)
5. For a detailed discussion of the technical design of the ALIS system and its links to sustainable building usage through the lens of behavioral psychology, see Velikov and Bartram, "North House: Developing Intelligent Building Technology and User Interface in Energy Independent domestic Environments," PLEA Annual Conference 2009 Proceedings
6. The project has been exhibited as part of the 2008 Young Architects Award program at the Urban League in NYC, the 2009 Twenty+Change Canadian Design Awards program, and has received funding through the award of the 2009 Professional Prix de Rome in Architecture to Velikov and Thün's practice, RVTR, to continue the design research initiated by the North House Project. As well as its review in Ripley, Thün and Velikov, "Matters of Concern: Problem Seeking and Complex Collaboration in a Post Information World" Special Issue: Alternative Architectures | Alternative Practice in Journal of Architectural Education (JAE), Volume 62: Issue 3