Design-Build at the Micro-Scale

A table-top project offers the challenges and rewards of real world construction to every student in the second semester.

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INTRODUCTION

Design-Build projects teach lessons that can't be learned at the desktop, and awaken modes of learning that students may never have experienced. However, the projects can only take place where resources, skills and enthusiasm are equal to the logistical challenges. And even then, learning may be limited by the very realities that make the projects so compelling. This paper describes a project that foregoes size to maximize other benefits of Design-Build. We are currently preparing for the fourth iteration of the project and report on a range of difficulties, solutions, and plans for the future.

The 4th Element is a compositional study of ten components including line-voltage electrical parts. It is colloquially known as "the lamp project", but it is not an exercise in product design, and the projects needn't provide light of any particular quality or efficacy. It is an exercise in the ordering of parts, the integration of systems, and the design of construction. It requires students to build formwork, to mix and place concrete, to work wood among other materials, to make various mechanical connections, to incorporate electrical and piping components, and to achieve structural integrity, artificial illumination, and passive ventilation. In a cubic foot or two, the exercise offers considerable breadth and complexity of experience. If the completed pieces are not product design, nor are they buildings, nor are they models. But they are built works, firmly anchored in reality. One simple ingredient that helps the students transition from the model realm into reality is a prohibition on glues and adhesive tapes. Of course, construction adhesives are a vital part of model glues, but students report that at this size of work, the action of bolting, lashing, riveting, socketing, banding, and so on underscore the material reality of their work. Also, to design and build a working luminaire is an awesome real-world responsibility. Students recognize that electrical safety, structural integrity, and sufficient ventilation are not abstractions, but questions of actual survival. And ultimately, what inspires consistent enthusiasm and effort is that the projects are almost always their

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own, concrete, unconditional, lasting reward.

Early iterations of the exercise did not run entirely smoothly, but entering its fourth year, many problems have been solved, and evolution continues. For teachers hoping to bring the learning advantages of Design-Build to a greater number of students, six features of *The 4th Element* may be of particular interest.

1. LIGHTENING THE BURDEN

The organizational demands of Design-Build teaching can be enormous. Logistical challenges include fund-raising, construction safety, permits, construction scheduling, purchasing, site insurance, trades training, transfer of ownership, commissioning, and professional liability, and may also include travel and accommodations. Managing all this is not for the faint of heart. The teachers who organize large scale projects, the staff and the institutions that support them, and that cadre of particularly skilled and motivated students on whom success so often depends must all be recognized for their extraordinary commitment. Yet we must also recognize that the extraordinary, by definition, is not the ordinary run of things. If we the design-and-build experience to be a more ordinary part of schooling, then we have to keep the organizational burden to an ordinary level. Sharing experience between schools and develop common platforms and resources are very promising approaches in Design-Build management. The 4th Element is a different kind of experiment, trying to discover just how small a Design-Build project can be.

The exercise specifies ten parts, no more and no less: one concrete base, two wooden structural pieces, three envelope parts of unspecified material, and four electrical components: an Edison-base lamp, a lamp holder, a switch, and a plug. There is no limit on nuts, bolts, or other connectors; wires and conduits are included in this latter category. Non-marring feet must be provided. In some projects these are purchased or made as hardware and counted among the connective elements, while in others the two wooden parts have become feet, or have been extended downward to provide feet.

In its first iteration, even this miniature project placed unacceptable demands on the school and on the students. Although it was the electrical aspect that caused

Figure 1: *Wharf Lamp: Alastair Bird*

initial anxieties, it was the concrete work that caused the biggest problems. Few students anticipated the complexities of their own formwork, more than a few failed to anticipate the hydrostatic forces generated by their pour, and of course, only a very few anticipated the hours of labor entailed in realizing their design. The consequences were borne not only be the students, but by our wood shop technician, by our custodial staff, and by anyone using the hallways.

Throwing students into the deep end may provide useful experience for one or two of them, but for most it will be discouraging or worse. Like most swimming teachers, the author doesn't recommend it. But in the first year of this project, as impressed as he was by his students' determination to succeed he was equally appalled by his own underestimation of the depth of the pool. This was not due to his inexperience in building but to the opposite: long familiarity with many facets of building had dimmed memories of his own early and untutored attempts. There may also be a generational gap between teachers brought up at least in awareness of model kits, tree-houses, and high school shop and students brought up on keyboards and pixels. To the extent this may be true, however, what students need to navigate unknown realities is neither warm nostalgia, nor cold showers, but information and coaching.

Happily, colleagues and students alike saw potential in the exercise, enabling adjustments to be made over the following years. For example, two preparatory workshops were introduced for first term students. These are not taken for credit but are required for shop access. Sessions are limited to six students, ensuring hands-on experience and providing the opportunity for real guidance as opposed to lecturing and blind trials. The "wood" workshop calls for teams of students collectively to make an implicit enclosure using a variety of material and connection types, each student responsible for one connection. The "casting" workshop calls for individual students to pour a plaster block in formwork provided, around a clay positive that is then excavated to leave an interior space. Both workshops are designed to stimulate spatial and compositional thinking as well as teaching some rudiments of making. These workshops also teach something about time, about working with technicians, and the protocols of the shops.

In the next edition of the exercise, students will also complete a small but structured lab in concrete work and one in low-voltage electrical construction. In the former, each of ten teams will make one pour, demonstrating assigned features of interest such as particular kinds of form tie or reinforcing, of internal or external formwork, of inserts, of mixes, and so on. At the end, everyone will have some experience of mixing and placing and finishing concrete, while the cast pieces and their forms will remain as a common library of techniques. Also, by way of preparation, students will make a small electrical circuit from a kit provided. This will include components and techniques from construction wiring, but will be energized with 12v DC.

In the first iteration of the project, everyone in the building (including many of the students) were struck by the sheer mass and dimensions of the completed works. Colleagues suggested in no uncertain terms that the author put a size and weight limit on the projects. Now, early in the term, as part of a planning application, students must give the dimensions and calculated mass of their proposed design. This approach appears to solve the size problem not through restricting ambition but by engaging the students' own sense of judgment.

2. THE DESIGN-BUILD CYCLE VS. THE ACADEMIC RHYTHM.

The professional's pattern that starts with the articulation of a brief and runs through project planning, research, preliminary design, design development, CD's, and construction supervision is already long. The academic context extends this process in several ways. First, there may be a preliminary phase of contract development. Even where the school or the instructor have been approached by an enthusiastic party, mutual expectations have to be worked out pretty carefully. Second, the designer is taking on the significant tasks and responsibilities of the builder, which demand their own critical path. Finally, the bulk of the work is to be done by students who have not yet mastered architectural design, and may only be starting to learn actual building skills. Inevitably, the pace is slow. Inevitably, additional time must be allowed for corrections. It is not unusual for several classes of students to rotate through a single project. In cases where early participants never see first hand the pros and cons of their design decisions, and where later participants end up simply executing or perhaps rescuing the designs of others, the learning potential of combining design and build can be diminished.

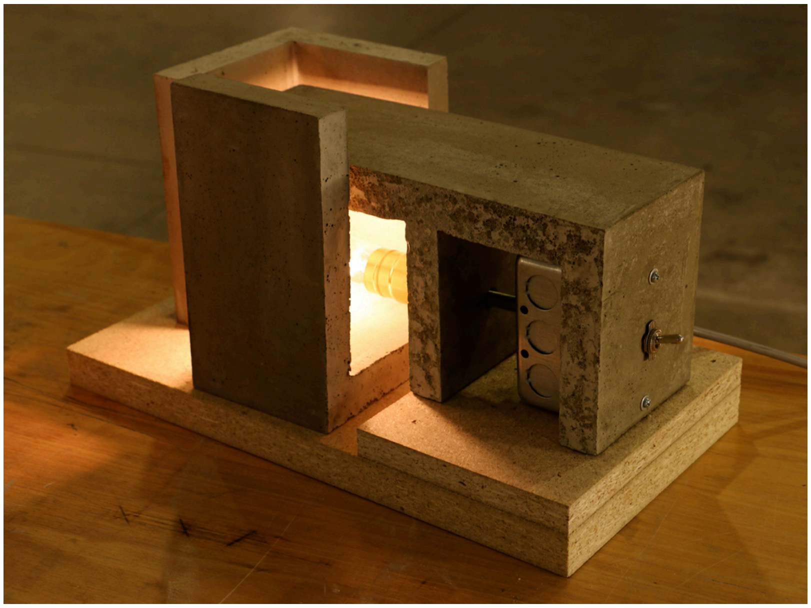
While it doesn't provide the learning potential of larger scale work, the miniature 4th Element project takes students through at least one complete Design-Build cycle. Over the years, an effort has been made not to extend the process – which would only invite more labor ¬ but to distend it, to allow for a more methodical and reflective approach. Preparatory exercises taking place early in the semester and even in the previous semester have already been described. Another effort continues, to tighten the project schedule.

Where students in earlier years were completely responsible for converting the instructor's suggestions and cautions into their own schedule, they must now meet a firmer timeline. The time gained has allowed at least some students with formwork or casting failures, for example, to complete satisfactory revisions in the original allotted time. As much as possible, actual deadlines are avoided, in favor of mechanisms that promote self-awareness and reward decisiveness. So time-slots in the wood-shop and casting lab will have to be booked from a limited list, as will sessions with technicians. The concrete lab schedule will explicitly accommodate "first" and "second" attempts. This may serve as a reminder that complicated pours are vulnerable to many kinds of compromise and outright failures. This approach to scheduling will hopefully promote a kind of learning that deadlines alone can't instill, and may even inhibit. And certain approval thresholds have been put in place which do not constitute absolute deadlines, but which do come with grading consequences that encourage methodical project development and delivery.

3. DELIVERY DEMANDS

Client demands and regulatory demands may inhibit explorations of the design half of the Design-Build equation. In the case of *The 4th Element,* the straightforwardness, decisiveness, and availability of the client both limits the realism of the exercise, and promotes energetic design study. Also, the micro - scope of the brief seems to allow a kind or level of investigation that more demanding projects can't always accommodate.

The project is organized around conventional construction approvals: planning, design, rough-in and finish. The final submission and exhibition is technically the least important threshold, and becomes mainly an occasion for celebration. The rough-in inspection checks for robust execution of the pieces as designed. Structural and ventilation issues are fairly self-evident, so the inspection focuses on electrical workmanship. Inevitably, students will have encountered unexpected problems in the construction phase, especially with regard to sequencing. Many of these problems do call for design adjustments. Changes need not be officially proposed and approved, but finished pieces still need to adhere to the principles learned in early lectures on wiring and grounding and early tutorials in electrical construction.



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Design approval follows a checklist provided at the outset of the project, covering not only the predominant electrical questions, but also ventilation, structural, and even programmatic issues.

The electrical design must describe the topology of the circuit and tabulate the type and ratings of the various components. A critical point is identifying whether the system needs to be grounded or not, and showing the ground where needed. Concerning ventilation, not all the early projects provided adequate cooling for their bulbs. To some extent this could be solved by CFL's and LED's, but more recent examples have stipulated passive ventilation, indicated on drawings simply by a blue arrow entering the lamp room at the bottom, and a red arrow leaving at the top. Quantitative structural design would be relatively meaningless, but one or two rudimentary diagrams describing lateral stability are required. The last few editions of the design requirements have also added a spatial program. In their enthusiasm for minimalism, some of the early builders neglected to provide passage for a human finger to reach the switch, or for human hand to grasp a bulb being installed or replaced, or for a bulb-laden hand to move into or out of the lamp room. Designs must now meet these spatial needs.

These latter stages of submission encourage methodical design development and sound construction. There is also an initial application to be made, for planning approval. As mentioned earlier, this includes a statement of maximum dimensions and weight; it also includes an explicit commitment to technical standards. But its main intent is to enable focused and thorough schematic design. To encourage this focus, students are asked to articulate a formal language or intention. These intentions have included "purity of form" "one color, many textures" "celebration of ready made industrial parts" "neo-plasticism", "evidence of the hand" and so on. Some years the author has assigned design languages (the word "style" would be controversial) on a random basis, with the ultimate possibility of trading or devising one's own always allowed, but encouraged to a greater or lesser degree. Surprisingly to the author, students report that the assignment of formal language is a positive experience, as it enables investigation of possibilities that may otherwise be seen as out of step or out of fashion, and as it enables them to enter immediately into design, without dithering about formal goals. It is made clear to the students that as

Figure 2: *The Fourth Element: Kristen Holmlund*

the exercise resides in a technology course, adherence to a stated design language will not be evaluated. Nonetheless, they take advantage of the efficacy and clarity that formal decisiveness enables.

The project calls for an orchestration of the ten parts and their various connectors. The parts are always ten: the concrete base, the wooden structural pieces, the three envelope components, and the four electrical parts. Students have discovered an enormous range of possibilities even in this limited palette. The understanding of systems orchestration began as a casual and implicit aspect of the exercise, but it has seemed worthwhile over the years to make it more explicit. Students are asked to map building systems both in a conventional, static sense and in a more dynamic sense of system borrowed from ecology and business. In technical design, the two become intimately entwined.

4. STUDENT WORK IN TECHNICAL TRADES

In the context of full-size Design-Build, critical aspects of systems integration and construction may need to be handed off to others or even left out of the project. The micro scale of The 4th Element exercise allows it to include M and E experience.

Liability issues will of course arise. Students have always signed a memo of understanding concerning the limitations of the project as a pedagogical exercise, and over time, this statement has been strengthened. Students acknowledge that nothing about the exercises qualifies them to do any un-supervised electrical work, that the ultimate authority for the course are published electrical construction and repair books available to homeowners and hobbyists. This year, work that is not deemed robust will not be returned to the student except with the undertaking to dismantle it.

It is not appropriate to evaluate an architecture student architect on trades skill, especially when the trade in question is not even being taught in a recognized manner. So evaluation of the exercise emphasizes technical design and project management over motor skills. The kind of craft that we expect in drawing and model-building is rewarded, but as a measure of excellence rather than of basic quality. What is essential for architecture students is to develop an understanding of what craft and workmanship mean, both in a trades context and in an artisanal context. In this regard, accurate self-assessment is worth more than manual achievement. It must be remembered that where a student opts for an un-grounded and pre-manufactured power cord and a keyed lamp-holder, the whole project can be accomplished with two electrical connections. This option reduces the anxiety level for inexperienced students, and is adopted by a small number. So while students are exposed to the nature of certification systems, authorities, inspections and protocols, they are not overwhelmed.

Questions of systems integration play a much larger role than questions of workmanship. The four elements and ten parts of the project offer some useful ideas for working with systems and for untangling taxonomic complexities. We begin with the four elements associated with Bötticher and Semper, and their subtly distinctions from the classical triad of base, walls and roof. The four elements start with a similar idea of a raised earthen base. Semper's superstructure is not divided into wall and roof as in classical construction or North-Mediterranean vernaculars, but into skeleton and cladding, as in modern construction and transalpine half-timbering. Semper's fourth element, again rather northern and modern, is the hearth. It is this energized system that is the namesake and inspiration for our own projects.

The four (or three) elements are not functional or dynamic systems; they are more like the spec writers divisions. Although some of the sixteen or fifty-odd divisions may be associated with particular performance area, ultimately they are defined not by behavior but by contractual extent. This year, students will be asked to list and to draw the ten parts and their four elements quite explicitly. They will also draw columns across the rows of their list, one for each functional system. In the cells of this matrix they will identify which part plays a role in what system. The wooden parts must be employed in the structural system, for example, but of course they can also play a role in the envelope and the lighting system. The envelope pieces may or may not act structurally. The electrical parts may play a space-defining role, or they may be hidden. The ventilation system may "have" no parts at all but exists by virtue of the form and arrangement of other parts. There is actually no limit to the kinds of functional and perceptual relationships observed or created between parts. It is this simple systems integration matrix that fosters thorough investigation of compositional possibilities, even within a particular formal intention, and within a short period of time.

5. GROUP AND INDIVIDUAL LEARNING

Larger scale Design-Build projects are generally undertaken by groups. Students reap the rewards of teamwork and learn to appreciate diverse individual contributions. Whatever frustrations may be experienced by newly formed teams of novice builders, they are more often than not outweighed by the satisfaction of achieving something beyond the individual's reach. This is a great lesson for a student in any building profession or trade. It is particularly important in architecture, because the notion of the architect as auteur, in spite of its limited resemblance to office practice, is so firmly entrenched in the studio system. This dimension of Design-Build is exactly what the 4th element does not provide.

It would be difficult to provide this experience at the tabletop scale. One could imagine re-writing it as a group project, but the losses might outweigh the gains. It might be possible to contrive a method for sharing labor and skills, but collaboration would never be imperative as it is in on a full-scale project. It would be difficult to discourage tasks from being meted out or taken up according to skills and abilities already acquired. Instead, *The 4th Element* provides a different kind of Design-Build challenge, confronting each student with every aspect, every decision, and every consequence. It is designed to expand the students' zone of comfort, of competence, and above all, of confidence.

6. EXPOSURE

0Design-Build courses tend to be electives. Yet if they offer important lessons that can't be achieved in simpler modes of teaching, then we should find ways of making some of these courses mandatory. Miniaturization is one approach. So while our project is miniscule, it is actually possible for an entire first year class to tackle it.

One might take this point a little farther. It is not unlikely that Design-Build electives attract students who already have construction experience, or those who have a predisposition for hands-on learning. So on the one hand, Design-Build electives courses offer worthy support for non-standard learning styles. On the other hand, it could be argued that the purpose of unconventional or tacit teaching methods is not to reinforce existing learning preferences, but to expand them. This meta-learning objective would be more readily met where every student was offered tacit learning opportunities . This daunting goal is more easily achieved on the micro scale. This broad exposure to tacit learning and to construction realities is our principal objective. If students completing the 4th Element are better equipped to tackle more ambitious construction projects later in the program, so much the better.