Five Houses: Sustainability Redefined

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James and I founded our practice 24 years ago and spent most of our first 15 years just trying to learn the craft of architecture and building rather quietly, beneath the radar screens in Philadelphia, just building and observing and learning and building and observing and learning. After about 15 years or so had passed, we decided we were starting to know something. We weren't quite sure but we felt we were beginning to know something. So we paused at that point to write our first book together called Manual and it’s basically about the craft of architecture. It’s organized around ten crafts that we used regularly and we thought about what a design would be. What we really found at that time though was that what was troubling us upon reflecting was that what we valued so much about architecture, the ability to craft extraordinary buildings, uniquely sited for the place that they’re in and for the purpose and the people they serve, is that we were getting further and further away from our ideals and not closer and closer. Our ideas or intentions on one hand weren’t getting closer to our capacity to see them through the form, they were actually getting further and diverging. We stopped at that point around 2000 a moment of self reflection we decided that we needed to explore this murky river between ideas and intentions and form and we tried to understand what was wrong with it. We found that a lot of things were wrong with this. What I’m going to do, briefly, this evening is to make two points: one at the start is about how we think about sustainability, which frankly, is not broad enough, not large enough, and not nearly ambitious enough. We’re never going to solve it until we do get more ambitious about it. The other that I’ll bracket that with at the end is some observations about prototyping, with reflections on the “proto” part of the word, the origins and beginning, and the “type” part, the very elusive part at the end of the word that our predecessors and ourselves are really trying furiously to get to and that has proved very elusive. And in between, I’m going to share a little bit about our personal journey or passage, which is really a set of research projects that have taken the form in this case of five dwellings that we’ve been working on over the last two years or so. That’s what I’m going to share with you this evening.

One of the things that we’re getting further away from, rather than closer to, is environmental ethic and environmental aesthetic. These are diagrams of the ecological footprint of Greater London. You can see the very troubling charts for electricity and water usage should we go forward with “business as usual.” You can see the electrical side, that even all the evolutionary steps that we have now begun to take aren’t going to do anything but hold ground. That’s a pretty troubling diagram. I would submit to everybody in this room, however, that the environment, as pressing an issue as it is, has really co-opted the word sustainability. It’s a much broader problem than just an environmental problem. By segregating and narrowing the term and using it as it relates to the environment we are actually hampering our capacity to solve the problem. This is an equally pressing problem of sustainability for us and a very, very disturbing chart.

I began my undergraduate career as an economics major and did that for two years until I moved onto other things, but I still like charts. I think they tell us a lot. What this tells us is that our industry, which is in red at the bottom (the construction industry, which we all as builders and designers of buildings are part of, and responsible for) has actually declined in productivity on the order of 20%. Some years we do better, some years worse, but overall, 20% down by the turn of the last century, over a 35 year period compared with the rest of the non-farm economy that includes us. This is deeply distressing. If you’re not really upset and fearful for the future of all of us and for the future of very large portions of our economy when you look at diagrams like this, you’ve got to search your soul. This is not sustainable. It basically suggests that we’re spending more time and more money to do less. The rest of the world is not doing that. The rest of the world is spending less time and less money to do more. That’s an equally pressing problem of sustainability.
Third, there’s the quality issue. At the same time that we’re spending more time and more money to do less, we’re also doing it more poorly than we’ve ever done it as a profession. The problems of quality in our builders today are more and more pressing. In the professional practice part of our life, which is about 90% of what I do, a huge portion of it is occupied with quality. At the end of every project, we have telephone books this thick, sometimes many of them, that enumerate thousands upon thousands of quality processes in our larger university buildings that are really the bulk of what we do. And that problem has escalated over the 20-plus years I’ve been in practice. I remember in a talk that I heard Tedd give, he cited a Florida statistic where as many as 40% of new homes in Florida suffer from serious moisture penetration problems. This, too, is not a sustainable path forward. What I’m asking you each to do this evening is to look at these problems and to look at that word “sustainability” broadly. Think of it as, yes, environmental problems, but in equal measure a problem of productivity or the lack thereof, and a problem of quality degradation. Look at that as a broadly based and unified problem. We believe in the end that if we take these on singly, we’re not going to make much progress on any of these fronts. If we can collapse them together with solutions that increase productivity and lower ecological footprints and improve quality, then we are going to be in a position where people are going to say yes. How can we say no? If you go to them and say, “I can tell you that we’re going faster for less money with higher quality and lower ecological footprint: are you interested?” I think we need to look at this as our sustainable problem. It’s very difficult and we spend a lot of money on professional practice days with clients with ecological footprint issues and they want to know how much more it’s going to cost them. These things all need to be seen together.

We decided in 2000 when we reflected on the state of our craft to reorganize ourselves about a research agenda. This is the structural diagram of our 62-person architectural practice in Philadelphia. Everything about it is organized to support research. Our workplace, our staffing, our finances, our communications, our marketing, and our technology all support research, but in turn, the arrows also go out. Research is also the kernel or the seed that generates the content, its substance and the soul of everything that we’re able to do. This has, for the last eight years, been the organizational diagram we’re working under. We have four areas of research that we pursue with our research team and all of the staff in our firm. The biggest one is environmental, and it crosses over into issues of system, material, and process. We have a number of initiatives under way at any given point in time, some that are developed to support our projects and some that are purely speculative and others that are supported by outside entities: researchers who basically hire us.

We move that research kernel around through all the enterprises we engage in. If you think of this as an egg, in the albumen of the egg you’ll see a lot of words that are all related to communications. That’s something that we take very seriously. Research does none of us any good if we don’t share it with each other and build upon the work that each of us does together into a much broader whole that has much more potency that what any of us can do alone. We take the communication part of our research agenda very seriously. But we do move that resource in our firm around in our projects into different types of projects and into a variety of enterprises. We’re nimble, unlike large corporations and the government. James Timberlake and I can just wake up one morning and decide that “everybody’s going to this side of the boat for the next two months” if we want to. And we do do that on occasion.

The first research project we engaged in back in 2001 when we received the Latrobe Prize was, we took all the money, hired a research staff, and we traveled all over the world looking at how other industries that were on the high side of that productivity curve, that had gained 240% since the 1960s instead of lost, as we have. We started to look at how they did things. We concentrated on automotive, aircraft, and shipbuilding industries. They all, for many years now, for about a decade and a half, have been required by their clientele, the people that use and buy what they make, operate under this formula at the bottom \[ER (Q \times S) = (C \times T)\], whereas we at the top continue to operate under this formula above the Prius. That formula basically says that if you want more quality and more scope, you have to spend in equal proportion more money and more time. In all these other industries, those that ran them basically say, “No, we want you to deliver higher quality and scope in the lowest amount of time and we want you to do so in an environmentally ethical, high performance manner that lowers the ecological footprint of our prospective industries on the environment.” That’s where we’re operating, at the

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top, but this is where the rest of the world is operating, and it’s where we need to get in order to have a sustainable future for us as a profession and for all that we do within the world to be sustainable for everyone who uses our buildings.

One common fact that pervaded all three industries, aircraft, shipbuilding, and automotive, is that, it varied from industry to industry but in the auto industry began in the early 1990s: they completely changed the way they made things. Instead of bringing 4000 car parts to Ford’s Dearborn assembly plant, they created integrated component assemblies through the reorganization of their supply chains, and downed those numbers of parts that arrived at the final point of assembly to as few as 15 or so. The dashboard on the right is an integrated component assembly. It’s got air conditioning and heating systems in it, a tremendous amount of information, electrical in it, it’s got finishes in it, and it has a structure in it that keeps that together and it keeps the engine from crashing through the compartment in case of a collision. It’s got 204 parts that arrive at the point of final assembly as a single part. That is what underlies the productivity progress for all of the other industries we looked at and it’s why we fundamentally don’t make any progress. It comes down to integrated component assembly: yes or no?

That allows them to become quilters in those industries. They can arrive at the point of final assembly. In our case it’s a building site. In the case of Boeing it might be their Washington plant. They can put together now, in as few as 14 days, a Boeing aircraft: a pretty complex machine in a very short period of time. Whereas we’re still weavers: we still have to work sequentially. We put in foundations, put up frames, weave other structure through the frames, weave other systems through the frames, then start to enclose the systems. We can only work sequentially rather than simultaneously. We have to move from weaving to quilting. The craft of the future for us is quilting.

Our profession, as most of you know, generally does not permit us to engage in means and methods of construction assembly. We allowed this to happen. We let the AIA do this to us. We let attorneys write us out of this. We have to change it. Frank Lloyd Wright, by contrast had contracts for the Usonian home, went so far as to say he aimed to eliminate the general contractor. This is something we have to engage in. We can no longer be contented by profiles of desired outcomes, but engage deeply in the means and methods and processes used to make them in order to make any headway and move forward.

Building Information Modeling back in 2001 was extraordinary. Today it’s almost already old hat to all of us, but when we first saw how Boeing was designing their aircraft in 2001 with solid models (this was before Revit existed or any other parametric modeling software in architecture), we saw an extraordinary future at that time: the capacity to have one drawing to control the whole enterprise. This is the key to quilting: without the capacity to build solid parametric models, you can’t quilt because you can’t trust your dimensionality. This is a central reason why the entire enterprise of offsite prefabrication failed on the part of our forefathers, and the entire reason why it actually has a chance of succeeding today. We can build all of this stuff anywhere in the world that we want with certainty that when it arrives, it will arrive and fit together.

With that beginning set of observations about what it means to be sustainable, and how broad the enterprise is, I will share with you five efforts of prototyping. In our own practice, I mentioned we do a lot of large buildings: performing arts buildings, university buildings, prep school buildings, government buildings, and it’s fortunate we do because we would never make a living off of houses (but they’re a lot of fun). We decided after working with our university clients that at best getting them to do one thing with each project that wasn’t “business as usual.” After three or four years of that, we decided that we weren’t making very fast progress, so we decided to shift gears and get back into single-family houses. I’m going to share with you five such projects over the past couple of years that we’ve engaged in.

The first one is a house for my family. If you’re engaged or willing to experiment on yourself, then you don’t have the right to do it to anybody else. We were going to do a family home and decided to make it an experiment, and that’s the spirit in which this house exists. It’s got a pretty extraordinary place, and one fact that is different about offsite fabrication for us than for the automotive, shipbuilding, and aircraft industries is that we don’t move. We’re fixed to places, and that’s what makes what we do different and it is also what makes it not
only potentially extraordinary and poetic in ways that ships and planes can never be, but it’s what makes it very complex. In the case of this site, we attempted to show that you could build an offsite fabricated structure that has, inhabiting its very soul and everything that is moving about it, that has the place that it’s located in as the driver of its physical form. All that exists about this house: the sun, the grassy plane on which it sits, the loblolly forest, the water that it looks out onto, all of those elements are reflected in the physical form and substance of this house. We thought of it certainly as a treehouse at the outset. It needed to be up, it’s on a barrier island. It’s foolish to build anything that isn’t elevated on the barrier island, so it needed to be up. We thought of it as a house in the trees. We thought of the house coming out of the forest, not being in nature, but coming out of nature, with these extraordinary loblolly pine trees that surround and bracket the house, and provide the backdrop to it, actually providing a lot of its formal substance. We thought of it not in a predatory way like the duck hunters. We thought of it as providing a savannah-like view that is so prized by all of us for obvious reasons. As human predators, we always want to see what’s coming at us: that’s a reason why we like these things that are up, and the views let you see out. We thought of that as the form-giver for the house. Then we literally composed the wood cladding system over the photographs of the loblolly forest, basically mimicking the passage of solid and light through the form of the house.

It’s a little house. It’s four rooms. You park underneath and go through a little garden, and then paths up a stair up the whole east side to the top level of the house on the far right. There are two rooms there: a big living room/dining room/kitchen area and then a bedroom and stair and a bathroom, and then there are two more bedrooms down below, with one more bathroom. So it’s a little house: four rooms, pretty simple. There’s a bridge interconnects the two halves of the house, so you can shut down one half of it if you’re not using it.

It’s largely an act of designing for assembly, rather than for construction. It’s largely assembled. We chose deliberately not to use that word, construction. It’s assembled. The central tool, while there were some hammers and saws on the site (we didn’t want them, but we couldn’t get around them) was a ratchet. These integrated component assemblies, the offsite fabricated integrated assemblies for the house: smart cartridges for floors and all the building systems, the scaffold to support those cartridges, the blocks, various elements of equipment like double skin operable west wall and the wall cartridges were all fabricated off-site and basically clipped to the scaffold system. The basic idea is that it could be disassembled without actually demolishing the house. It’s not about construction, it’s assembly. At the end of its life, it’s not about demolition, it’s about disassembly.

The first and most important act of design was an architectural supply chain. Tedd is going to talk to you more when I finish here this evening about supply chain. This is the most vexing and troubling part of the problem. It’s not how to design a house that can be assembled and disassembled, it’s about how to find the collaborators to actually do it, and they’re few and far between. James and I searched the world constantly in search of collaborators. In the case of this house, Tedd was the only one who would actually take it on. They’re few and far between and there’s not much spirit of adventure out there and not much capacity to improve. Tedd took on the role of fabricator and assembler. You can see the supply chain that he managed to the left. We hired a site builder, Arena Program Management, to take care of the supply chain to the right. We tried in our own halting initial way to organize this thing the way the automotive industry organizes its supply chain. I would submit to all of you that this was our most important act of design. Nothing about the form of the building which I personally consider beautiful. It moves me every time I’m there.

At the time it was done, it was one of the more comprehensive parametric modeling efforts ever undertaken for a building anywhere in the world. We worked on Revit, and Tedd worked on CADWorks, and we translated between them. CADWorks is what Tedd uses for all his cutting and shaping and forming directly from the parametric models. We worked as a unified team and built the model together from the outset. We began, and when we entered what we think of as design development, they were also drawing and working on it, sharing and building the model together as an architect-builder team. Then we brought it into all kinds of things: supply-chain management, dimensional control, digital fabrication, even energy modeling and calculations of life-cycle and energy cost analysis.
Here's the scaffold going up. Four of Tedd's carpenters bolted the whole aluminum scaffold together in four working days. Long days: they went to sites, they got up early in the morning and they worked past sunset. We ordered all the pieces for the frame directly from the parametric models. We built the model, we generated the parts list, we emailed the parts list to the supplier, and they fabricated and extruded to the exact lengths we wanted, without any waste, all the aluminum in the house. They shipped it directly, so we eliminated a lot of aspects of our present supply chain stream, things like shop drawings for this element of the construction. We were able to reintroduce the control of craft that I began this talk with this evening. That's what really motivates James and I and all of the architects in our firm: it's the capacity to have the idea on the left become the form on the right, not the collection of things that didn't work out. We got precision here. Tedd's guys would argue with Marilia Rodrigues, our project architect. If there was a millimeter lost to the model, they would have an argument about where it was.

Tedd used our model and his CADWorks model to drive his digital fabrication equipment. We still had to do some hand assembly. In his plan you can see the radiant heating system for the house being installed by a plumber in Tedd's factory. You can automatically see the improvement in the whole system. If this were being done in the field, he would be working on a ladder, upside down, in bad weather. He's working inside, in a temperature controlled shop at a good working height, and he's working with the floor turned upside down. He can orient parts so that he can be a better crafts-person, with less wear and tear on the body.

Here are the pieces being lifted in. You can see the smart cartridges that are loaded with the radiant heating system, a microducted ventilating and cooling system that I'll tell you about later. Electrical power goes into these, lighting goes into them, ceiling fans go into them, smoke detection systems. All the wiring systems for the house are contained in either these smart cartridges or in these blocks: bathrooms and mechanical rooms. You can see these being fabricated in Tedd's shop. They come to the site with all the mechanical systems in the upper right completely installed, and then they're plugged into the cartridges on the site. The elements of the bathroom: the fixtures, the mirrors, and the millwork were installed in Tedd's plant, everything except the towels. All of those mechanically intensive things that take lots of time and become extraordinary drivers of the long schedules of our projects: eight different trades trying to get into a 5' x 7' bathroom. That alone is going to take months and months of time onsite and it becomes a real driver of the schedule. It's all integrated here. You can see these blocks being lifted into position. This one has a mechanical room under a bathroom; the other one has a mechanical room to the side of a bathroom.

The last element that we're going to talk about is equipment. The house has a lot of equipment. We bought the kitchen for the house from a company called Craftmade, and we did it online. We took the elements out of the catalogue, designed it online, we then ordered it online, it came in kit form, and it came basically assembled like the rest of the house. The stairs were the same way: there was a kit spiral stair built up of multiple sections that three guys put up in four hours. The exterior stair was built at a metal shop in Philadelphia in two sections. Two sections put in by two guys in two days.

This is the outcome. A house that is about living, it's about science, it's about how to open itself to the natural world, and it becomes in its own right a really substantial environmental agenda that goes beyond the materials that were used and designed for disassembly. We conceived of the house mechanically as a filter, not as an envelope. The house on the left is a conventional developer built house you see all over America. The fundamental premise is that you seal the house up to the external world. We use machinery and horsepower to control the environment between the outside world and the inside world. Lobolly's conceived more along the lines of the little pine shed on the right that has a filter. It's a system that selectively lets in what we desire of the natural world and keeps out what we don't desire.

That's what this piece of equipment does. It's a double skin active wall. It is used for a solar shading system. The house does face west so it allows us to shade the sun from entry into the house when we don't want it. In the winter when we do want it, we close it as in the diagram on the left. It becomes a thermal blanket that wraps this glass wall of the house. The basic idea here is that if a typical house in the US is maybe 35-40% open, we were aiming to get a substantial part of this house operable and openable. Instead of designing for aver-
ages, we could design for the extremes: for very hot and very cold days in a way that wouldn’t require the use of systems, or lessen the use of systems to heat and cool the house. I would submit this is a fundamental environmental problem for every building in the world right now: designing for averages. We don’t design them to adapt to extremes. Averages are very few days in the year. Extremes are a wide range of performance. It is essential to how we can move forward and save energy.

We monitored the house during the first year of occupancy, and the dark red at the bottom of this diagram is the thermal blanketing effect of the house when it’s closed. Basically, what that diagram tells you is that we get about 30% of the way between the desired interior temperature and the outdoor temperature in the winter just through the thermal blanketing effect of that double skin, by trapping the sun’s rays on that envelope around the perimeter of the glass wall. It allows us to basically instead of having a hearth and a porch to just have one room that can be adjustable: to become hearth or porch.

This building, as I mentioned, was designed for disassembly. It just won the EPA’s first life-cycle building challenge for its design for disassembly, for the fact that it’s developed to be disassembled rather than demolished. Very few houses in America ever make it to 100 years. You have to ethically start taking responsibility for the end of the life of what we’ve made, not just for the origins, the forms that we bring into the world. This may be its fate someday: it may end up on eBay. This is fundamentally about feeling the natural world on the one hand and bringing the natural world selectively into the house, and developing the house formally and artistically as an environmental aesthetic on the one hand, as well as an environmental ethic. It’s about the production of a house: how we actually build something and unbuild it at the end of its life. Every aspect of the form of this house, its aesthetic, derives from those two elements. This isn’t going to mean much if it just continues to exist in the world of prototypes. We have worked with Living Homes in Santa Monica, California to try to make this into a product. We believe that the million-plus single-family homes put up in the US every year and several hundred thousand multi-family units have very little environmental ethic built into them, largely because they have been built by relatively small builders who don’t have the desire or knowledge or economic capacity to develop environmental high-performance buildings. We believe that if we can concentrate the making of parts in a not insignificant number of factories that that’s where we can really build some really strong environmental performance into our smallest buildings: our homes. They are the buildings that occupy the bulk of the built world. We think there’s a passage forward here from these prototypes to an environmental performance agenda to offsite fabrication.

Steve’s website, if you’ve seen it, has a number of different dwellings, from single- to multi-family that we’ve designed. He has one of each under construction. You can mass-customize to a limited degree the dwellings that he sells. They can be oriented differently, for urban reasons, toward a street. This is the one that’s in fabrication right now for the International Builders Show in Las Vegas, as a prototype. This is one that is a multi-family dwelling in San Francisco, in the Presidio.

The third house I’ll share with you is in New Orleans. It was designed as part of a competition that we were invited into by Brad Pitt for the Make It Right foundation. It is designed as an 1100 square foot home for a family that lost its home in Hurricane Katrina. It has very tall, 11 foot high ceilings, large windows, a lot of different shading systems to shade the dwelling. The first one is largely going to be onsite built, and built more conventionally, but we hope to move with subsequent versions of it, and he’s building about 250 homes as part of his commitment to the Make It Right foundation. The idea is that we want these dwellings to be built onsite in small factories in New Orleans, because a huge part of the problem there isn’t just homes, it’s jobs. They have a lot of housing to rebuild, more than any place in the US. They could become the center of offsite fabrication, provide jobs for the population so that when they’re done building their own city, they can export that skill to other cities and become a leader in the job market for offsite factory fabricated elements that make up houses. That’s the passage we hope to take with successive houses. They’re high performance houses environmentally with a lot of low-tech high performance features related to water management, energy management. They really have an extraordinarily low ecological footprint. Here it is going up: this house was put up in basically six weeks. This is about a week later, with TrusJoist floors going up. It uses a SIPs panel wall system, with insulation wrapped in aluminum. They then actually cut out the windows with a sawzall and stick the
windows in on the site. Here is is just before
the hurricane that went tangentially through
New Orleans at the end of August. Largely
done at that time, it suffered no damage. This
is the family that is now living in it. The whole
house is six weeks, start to finish.

The fourth house is one that’s in development
in conjunction with the University of Pennsyl-
vania. James and I teach at Penn and the Uni-
versity of Washington-Seattle. This is the sec-
ond of a five-year program, in Dacca, Bangla-
desh. It’s an extraordinary city. On the right is
the population density of my home city, Phila-
delphia, which I think of as a very dense,
walkable city by American standards, but com-
pared to Dacca, Bangladesh, it’s nothing. The
density of it is 220,000 people per square mile.
This is old Dacca. Even in the context of Dacca
itself, an upscale neighborhood right across the
river. It is extraordinarily incredibly open and
dense by American standards. Even with
largely one-story buildings, you can see the
extraordinary density. These are some views of
the place from above. These dwellings regu-
larly flood, not every year but close to it. The
people who live there have developed a way of
moving up as the water rises. The last thing
you want to do is leave your home, for obvious
reasons. They move up and they only ulti-
ately abandon the house if the water rises
well above the roof, and they can’t stay. They
take off in tethered rafts that they leave up
there. This is not what our students at Penn
thought they were signing up for when they
first came to Penn, but they spent a lot of time
doing cost analysis of the types of dwellings
that exist in that slum now and life-cycle cost
analysis of those dwellings. They spent a lot of
time thinking about economic models that
could sustain architecture, to make it become
sustainable economically, not just environment-
tally. They thought about ways to make archi-
tecture into ways to make money.