Keynote: Adventures in Prefabrication

Adventures in Prefabrication

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I'm a carpenter, so I'm not going to give you a lot of theory. I own a company, but at heart I'm a carpenter. I think like a carpenter. For the architecture side, I hire architects. For the engineering side, I hire engineers. I love building, and that's why I do this. I learned carpentry as a young man in Colorado Springs. I'm the sixth of eleven children. My mother is the daughter of a missionary. My father was a minister. As soon as I was physically able, I was out working. If I wanted to buy clothes, I had to work. I was on construction sites when I was in junior high school. I'm from a very Christian family, and I can tell you that what I learned on the construction site, I couldn't tell my mother. I learned how to swing a big hammer. I learned how to swear. I learned some pretty crude behavior. Honestly, everything about the construction industry, from Colorado Springs, which got its roots from Cripple Creek, Colorado where they were building mining towns. This was a very low-skilled, low-class kind of behavior that was happening out on the construction sites. In the years that I was doing construction in Colorado, building tract homes, I was involved with more homes than I've built today as a professional. We were out building 100, 200 at a time. I was part of a large crew. Ethics weren't involved, good construction standards weren't involved, good human behavior was not involved. Still, I loved to build. I loved to see things go up in the air. I love that physical activity. You drive those nails today, you look back at what you did, and you can see it. You can measure it. You can calculate it. You know exactly how much you did, and you know how long you did it. I hated the process. I loved what we were doing.

I went from there to Cambridge, Massachusetts. I was trying to go to a bigger college at the time. I needed to earn a tuition, and I needed a job. There I was on construction sites anew, and I learned something completely different. I learned about the sacred profession. I was working with a fifth-generation carpenter who told me that he was the luckiest man in the world because he got to build for people. He got to do that thing that had so much meaning and value in their lives. He had choice: he was a graduate of Harvard University. He could quote Yeats for half an hour. Or: he could teach me about the framing square. He chose to be a carpenter builder because the incentive was the noble, sacred profession. I went from Colorado Springs, where I was banging nails, to being at the foot of this incredible mentor, this fifth-generation carpenter, who told me something different. I got to work on buildings that were 250 and 300 years old, and still working, still living beautifully. I was leaving buildings that I had worked on in junior high school that no longer existed when I was in college. I saw both ends of the building profession. I fell in love with this.

The fellow's name was Oliver Chase. I said to Oliver: how can it be that in 1971, we are building worse than we did 200, 250 years ago? How is that possible? How did we allow it? Why isn't there a law? Oliver took me under his wing. He could see that I was passionate and naive, and he began to show me the buildings in the area: why they survived, what kinds of craftsmanship went into them, the spirit of craftsmanship, the spirit of good design that led to the beautiful buildings in the Concord-Carlisle area of Massachusetts. Through Oliver, I got a job in Walpole, New Hampshire to work on a very modern home. It was in a very traditional, old community, and there again, I saw these fabulous old buildings that I hadn't seen in Colorado. I fell in love with building craft, and I said to Oliver, "I'm going to do this, but I'm not going to do it the way traditional builders do this because they're messing it up. We're losing that great tradition that built this country, and there's got to be a better way." Oliver was at the end of his working period; he had actually retired, which is why I went to Walpole, New Hampshire. He was basically retired, and he said, "You go, boy." I was lucky to meet him, and he died just a couple of years later. I still credit Oliver with bringing to me a passion for this building trade.

On the previous slide that I just flipped by, showed me. One of the first things that I did when I got to New Hampshire and I found myself on my own is I tore down three barns and

I built a woodworking shop. In Colorado, I had also learned a little about cabinetmaking in trade school. It was hard to get a job in the New Hampshire area, so I built a woodworking shop and I was building cabinets and furniture. The winters are long in New Hampshire, and you have to do something. There I was in a woodworking shop, with stationary equipment, building bathroom cabinets, kitchen cabinets, nothing terribly extraordinary, a little bit of furniture. What I learned was that this shop environment is fantastic. We can control everything. We can control the atmosphere of the air, so we can make sure that this wood is dry and it will stay dry. We have great equipment. We have a bathroom right around the corner. We have everything to make this a civilized, productive, efficient environment. Having fallen in love with the timber-frame tradition, and having asked Oliver the question, "Why did we lose timber-framing, for goodness' sake?" He said, "Because it's no longer efficient." I said, "We'll see." I decided to reinvent timber framing. I didn't know any better. My idea was to build it in a shop: that is, to precut the timbers in the same way that I made cabinets, using stationary equipment, using that good shop environment where I could control everything. What I didn't think about is: I was prefabricating. This was prefabrication. I was precutting, to very exacting standards, pieces that were made in one place and shipped to another. I prefinished them, I precut them. I did not prefit them because I would have lost the efficiency. The challenge of this craft had to do with, "How do you get precutting and shaping things and taking them to another?"

In 1975, I built the first one. It took me two weeks with another fellow, just to raise a timber frame. It was a long time, it was hard work, and it was rough. Some of the things didn't fit as well as they should have. That became our industry. That became my business. Timber framing took off. Between 1975 and 2004, we continued on this track. But in 2004, we made our building elements: the timber frame, the wall, roof, and floor panels, cabinets, doors, stairs, trim, and ceiling panels. In 2004, it took us ten days to complete the entire insulated shell. It's not a miracle: that's 28 years. Over the passage of time, we learned a lot, we got efficient, and we added a lot of building elements to our quiver of tricks.

After we had decided to reinvent timber framing, what we found is that we were in the business of also developing a whole building system around that timber frame. It ended up in Advanced Cooler Manufacturing in upstate New York, stress skin panels (we call them SIPs now). They were doing this for walk-in coolers. I took the idea, went back to my shop, glued plywood and sheet rock together and said, "Looks like a stress skin panel to me." I glued it in one day, using cement bags to put weight on it while the glue dried, and the next day I stretched it across two sawhorses and used the same cement bags to weight it down and see how strong it was. It passed my test, and within a year, stress skin panels were on one of our houses. That was 1977. There was no industry, there were no SIPs manufacturers. I talked a local company into making them for us. From 1975, when we started timber framing, 1997 we added SIPs panels to it. A lot of my colleagues and friends began developing timber frame businesses, too. We were building some of the most energy efficient buildings in the country. This is right in the middle of that 1970s energy crisis. We found that people weren't coming to us for timber frames, they were coming to us for these very energy efficient buildings that happened to go up very quickly. It involved two very high quality building elements: the timber frame and SIPs panels. Out of this grew a timber framers guild that now has 3500 members, 400 companies throughout the US. SIPA, the Structural Insulated Panel Association, that has about 100 companies all throughout the US, is growing. There's a new SIPs company in our area that was just established a month or so ago. Even despite the recession right now, that's an industry that's growing. There's a national reach, both of us have specialized equipment, we now have building code recognition. You get some insight about the power and the meaning of building elements. These are just two: SIPs and timber frames. They've spawned hundreds and hundreds of companies, national organizations, a whole livelihood. That's just the beginning. There's a huge opportunity out there.

In 1998, we turned a corner. We had been building timber frame buildings with SIPs enclosures. Both of these elements were shop built and site assembled. We decided in 1998 that we really wanted to go further. If we can cut the timber with compound joinery and take it a thousand miles away and get a fit to within 1/32 of an inch, we surely can do that for a floor, a wall, a roof section, a ceiling panel, a floor panel, and anything else that goes in the building. We decided to make our own panels, because we simply wanted to add more value to the building component. The SIPs was good, but it had some problems. Number 1: because

we were working in our own facility, we didn't like the waste that was associated with cutting out windows and doors and roof angles and that sort of thing. We're not going to be responsible for filling up our local landfill. Besides, we'd really like to make bigger panels. We'd like the panels to be integrated with wiring, and plumbing if necessary. We want to be in control of all of that. We wanted to add value to that. We began to develop our own system, and Steve's right: there were a lot of prototypes we tried before we found one that worked for us. Three iterations are on my house, an addition, and my barn. The barn roof is a little bit of an embarrassment, but it never made it to the market. We finally developed the ones that worked for us and that worked as a produced. In 1998, we built our own facilities to build the panels, and basically the things took off from there. Not only was it a more complete product, it was a better product, we can enclose our buildings more quickly. We were doing SIPs as roof panels, and we still do that for most of our projects. SIPs as a roof panel doesn't have the same waste factor, and our buildings are designed and organized with a modularity that the standard SIPs dimensions fit.

We developed our own floor panel with open cavities and a ceiling system. From 1975 to 1995, we were in the business of making timber frame shell packages. That meant the complete shell of the building would be under our control after we had done the design and engineering. We then left the rest of it to the site. We have good stories to tell about that, and we have some very bad stories to tell about that. We've done it for a lot of years. We have a good reputation. We have some very successful buildings around the country. However, my business keeps me humble. We've done some great things: Loblolly is definitely one of them. We have some good successes, but in the building business, if you're not a humble guy, you're not paying attention because there's a lot of things that can be done better. It sure is difficult to get a call from a client, two-thirds of the way through a project, saying, "Tedd, your guys did great. We love the house, but the local contractor is now a third over budget and we're only two-thirds done. We're going to be out of money. What can I do?" Well, what can I do? Pretty difficult situation. We've had quality problems, we've had a lot of problems. I have stories to tell, both good and bad, but the bad ones are the ones that keep me awake at night. The good ones keep me charging forward, the bad ones make me say, "there must be a better way."

From 1997-2008, we really decided that we needed to get beyond the timber framing. We need to develop a system for the entire rest of the house. We need building elements that will allow us to go from A to Z, to start at the foundation and go to the kitchen cabinets. If we can do that, then we'll have control of the whole house. We know what happens in our environment. We don't know what happens in anybody else's environment, so let's control that and the whole building.

In 2004, we established what is called the Open Prototype Initiative. It's a partnership with MIT and industry partners through MIT to do exactly this. What we were trying to do together is to design and prototype building elements that will lead to the ability to fabricate entire buildings off site, in controlled environments, with higher values, better systems, more complete systems, more "plug and play" ability. To make this real, on a regular basis we will build prototype buildings to demonstrate the R&D and the ideas that were generated through the discussions and the development of the team. In 2005, we built Crotched House, which was the first of the Open Prototype Initiatives. It is a very prosaic buliding by Kieran Timberlake standards. On the other hand, it's a very, very functional building that is serving a good purpose. It's at the Crotched Mountain Rehabilitation Hospital. It's a brain recovery center and a recovery halfway house. It has two separate residences, three levels, a staff area, four bathrooms, two kitchens, an elevator, and all of the equipment that you would expect in a hospital environment. We committed to build it from the foundation to the last piece of molding going in place in twenty days. We didn't do it. We had monsoon rains. We actually failed in a couple of other ways. We didn't fabricate as much as we should have. We left some things for the site that cost us dearly. They seemed small when we left it until the site, the wiring at this level is not that much, it can wait until the site. It cost us dearly. It took forty days. Forty days is still pretty good. The things that we didn't do in prefabrication: roofing, flooring, and foundation. Everything else was built in the shop. Here are the walls in production, the siding going on. Roof panels: this was a complete innovation. This was a very energy efficient building. We were striving for the design heat load of 10 BTU/sq. foot, which is a lot of insu-

lation. These are R-50 roof panels; the wall panels are R-35, so they're heavy and fat.

This is a mechanical core: it has plumbing, heating, wiring all integrated into the central assembly. We now have two manufacturers who will make those assemblies for us. This one was made entirely in our shop, but we now can send out the design for the assembly of these plumbing manifolds, and we can get them prebuilt for us.

One of the most challenging aspects of this was the elevator shaft: extremely heavy, extremely difficult to build horizontally when it goes into the project vertically. The tolerances were very, very close for an elevator shaft. We learned a lot in this little task.

Next came the Loblolly House. Steve has told you about that. I want to say that this was an incredible opportunity for us. We were fortunate to work with Steve and his staff. He really pushed us and pulled us. Steve said something about my hoping that we'd take it on. We learned so much together, and Steve, I've got to thank you publicly, and I'll do so again and again. We both have open wounds from some of the lessons, but I would do it again in a heartbeat. Such a beautiful building, and we're so proud to have been a part of it.

I thought it would be fun to show you a current project. This is where we are right now. Weston House is going to be on This Old House: 16 episodes, starting next week. We are working with Tom Silva, Norm, and his crew. It's a very interesting building because the clients are interesting and have eclectic tastes, as you'll see. By their wish, it was inspired by the barns of Western Massachusetts. Because of their inclination, we sought LEED certification, and it looks like we'll get LEED Silver. It has a very high recycled content. It has the maximum building elements that we could bring to the site: close to 70%. It was designed in every way for quick installation, easy access to all the mechanical systems.

There is a model of the building before we got started. This is a model right out of our CADWorks software, with a little rendering added. Once the model was designed, we got into the construction process. That model feeds information into CNC equipment. Here we are building wall panels; these are also R-35 wall panels, so there's a pretty big buildup, a thick assembly. This is something that we're going to try to solve. My issue with this type of assembly is that there are something like 60 or 70 pieces in a wall. Whether we do it in the shop or on the site, that's a lot of pieces to put together. Our goal in a few years, working with a couple of very good companies who are partnered with us, is to get this assembly down to three. I think it would go quicker.

Here we are in our facility with this Weston project. You can see that we've set up a gantry so that we can work on the walls, both interior and exterior. The sun shines every day; people can work standing up. That wall on the right is very high up in the building -- we could be up on the scaffold.

This is site assembly, day three. There's a lower level that you can't see.

At the end, a cupola that was shipped from our facility: a very big component that just dropped on the building. If you happen to see this on TV, it went very quick finally, but it was actually take 11.

Here we are stitching in the finishes. This is part of the craft of assembling on the site. We do most of the finishes in the shop, but you stitch on the site. Most of those cedar shingles were in place, but we had to stitch in the corners, stitch in vertically and up to the chimney.

This is from two days ago. They just dropped in the iron stairs that have timber treads. I talked about the high recycled content. The timbers came from the Rock of Ages quarry. They were the masts of the huge derricks that they used to pick up the granite blocks. They'd been in the Rock of Ages quarry for a hundred years. They're massive: they're 35 and 40 inches in diameter. When we got them, we basically sawed them like logs. Everyone was disappointed, because there was not a lot of evidence of their recycled history. There were no bolts or nails deep inside these huge masts -- it was just beautiful lumber. The other, curved timber has a very interesting story. When they did the Big Dig in Boston, at one point they bumped into a pile of timbers. It was in the location of the old Boston Naval Shipyard. They discovered that it was an entire inventory for a ship. There were 280 timbers that came out of live oak. They were harvested in South Carolina or Georgia, hauled up the coast as ballast in a ship, brought to the naval shipyard, sunk there to season. That would have been in the early 1800s. They were for-

gotten, or maybe metal took over and they didn't need them anymore. There was an entire inventory: shaped, marked, big long ones for the bow, little short ones for the stern. These are extraordinary timbers. The building has history even before we built it.

The next project is a BrightBuilt barn. The architects on this project are Kaplan Thompson Architects in Portland, Maine. Great firm, we've loved working with them. They've done a really nice job on this building. We're shooting for net-zero, there's super insulation, and a continuous online energy and building performance monitoring system. It has a solar thermal system. They are positioned for LEED Platinum. They shot for prefabrication, however they left a lot of things to be done on site. They're participants in the Cascadia Living Building Challenge, which is even tougher than LEED. The other hallmark of this is the open source collaboration for all of us: the engineers, the architects, building systems specialists working together to develop the parts of the building.

I love the idea of this building. It's very small. It's meant to be a one- or two-bedroom building, or a studio. Around the perimeter are LED lights that light up in conjunction with the monitoring system, so it's kind of like a mood ring. When it's green, the building is producing a lot of energy. When it goes to red, then it's not. It's not only producing enough energy for itself, it's actually producing energy for an adjacent building that's a primary residence.

Here are their panels in our shop, timbers on our cutting machine, wall assembly, and then on site, it took us two days. Why? Because it's small and simple, and we were doing only the shell of the building. This is from just a few days ago. They now do have the siding on the building. This project started at the same time as the Weston House, but we prefabricated nearly all of the Weston House. We didn't prefabricate all of this. Although this is less than 1000 square feet, and the Weston House is close to 3000 square feet, this is behind. We're going to finish the Weston House first, in about three months.

Here's our big project at the moment: Unity 2, the second in the open prototype series. It's also a LEED Platinum: we think we're going to get it. It has net-zero capacity. I say that not because I doubt that the building can do it, but my thing about net-zero is that somebody has to live a net-zero life, and that's the other part of the deal. The building can be capable of net-zero -- and this one surely is: there's a very, very small load -- but the occupants have to play, and they have to work hard so that their life doesn't consume more energy than it should. That's different from the way that most of us work on a regular basis. I would not fault them if they didn't do it. I don't think that I'd live a net-zero life on a regular basis. We neglect to talk about that when we talk about net-zero buildings. The other part is hard, to live that way. This is an extraordinary building as part of our open source involvement with MIT and some very good partners, including Dow and Huber and Kohler.

The other part of this is the open built woodworking components. The open built system that we've developed has to do with disentangling the buildings so there are locations for everything and that you have access to everything. In our concept, we've reorganized the building so that it's not entangled as most walls, floors, and roofs are. Everything is very specifically organized, with a location and with access. We developed our open built interior finishes, baseboards, full height panelling, and multiple finish options for ceiling panels and millwork. It has a movable wall and another divided partition wall. We're getting patents on these. We put a lot of effort into developing these wall systems, which basically separate the mechanical areas. They go in very quickly, and they're modular. We have a panelized ceiling system with a lot of options. These ceiling systems are integrated with a conventional joist or TJIs, and they allowed us to hang -- like this suspended ceiling here, but in a different way. Ceiling panels would give us access to the cavities.

The design of this building is architecture as pedagogy. Because it's at Unity College in Unity, Maine, it's a classroom. It's a place where there are board meetings. It's a place where the students interact every day. The idea of the building is that they can use it to teach, to learn, to monitor, to live. Just like Loblolly, it's designed for disassembly. It's design as a composition from a library of components that are common. The idea is that all of these components could be in production in separate facilities, and they could come together on a unique building, and they could create a unique look and a unique shape while the parts and pieces are common.

The design concept is a separation: there's a mechanical part, a living core, and a solar center. Here are the building elements that make up Unity House. The idea is to shrink many, many thousands into just a few. We got to about 45 for Unity House. Add as much value to each of them as you can, and you've got a system.

We put together the construction sequence for this building. We could imagine how we would put it together. Here are the walls in production. This was a tough one: these are R-40 walls. That again is a lot of layers: it's about 14 inches from the outside surface to the inside surface. Here's some of the assembly thermal and moisture analysis from Dow, in developing this wall system. Very interesting building science. We're really lucky to be able to work with a group of people who have great intentions in the work that they're doing. They didn't require us or even ask us to use their materials. They were thrilled to be working with us, thrilled to help in the engineering and analysis.

Here's one of the modules. There were two big ones. Controlled working conditions. It was Steve's mantra, it's my mantra. We can do extraordinary work in this type of environment. How many construction sites have a classroom? We have a classroom, so guys can be in a classroom in the morning, learning how to do a detail around a window, and for the rest of the day, they can execute. We have classes at least once every two weeks, and sometimes three or four a month, on various things that are going on, new systems for new buildings, something new that we're trying, why did that last thing fail? It happens on a very regular basis. In fact, half of the day tomorrow is classroom.

Here's a roof panel. This is the R-60 roof panel. It is a lot of cellulose, but it's a lot of technology, too. Flat-pack shipping: this is the reason we don't do modular construction. We add as much value as we can to our buildings, but we pack it tight, and we ship it with that value intact, and assemble it on site. With this system, there's no limitation to design. I'm showing you very traditional buildings, Steve showed you something very different and wonderful. We can execute them both as easily out of this environment because we have limitations on the components themselves, but it doesn't limit the building.

Here's some of the site assembly: floor systems, roof systems, and after five days, a complete enclosure. PV installation, and two weeks ago, close to finish. We have one more visit up there, and there are some boards are on that roof system, and one more wall to put in place. They're already having classes in the building. It's just delightful for us to see, because this building has so many functions. It's the president's house. The president meets with visitors there. The board meets there. They have classrooms there. Because of that, with their blessing, we've left a lot of things open. The mechanical room has glass doors, so you can see what's going on with the PV system and the thermal hot water system, and you can see if the building is generating energy or using it. We're offering it for sale. This will be on the market in the next couple of months: 1000-2500 square feet. It will be net-zero capable. It will have a number of renewable energy packages for different parts of the country.

This is my favorite project. This is right here, just up the street. We are so fortunate to be able to work with some amazing people, but we don't always work with someone who's a builder and a professor in building materials technology. It could be a nightmare! But it's not; it's been wonderful. We're the most fortunate company in the world to have customers like the Fisettes, who pat us on the back and collaborate with us. Paul has been an amazing collaborator with us and has helped us to develop our systems and develop our ideas. He's introduced us to some new materials and new technologies, and they're getting executed on this building.

Here's work going on with Paul's panels. We see the interior drywall on one, clapboards on another, the open wiring chase on the bottom. Floor panels going into place. Wall panels. The house is taking shape. The bathroom modules: there are two. The lower one is already in place, and this is the upper module. Roof panels. The skirt board is on and the last clapboards are in place.

Beaver Kill, New York: I did this as another project that's in the field right now, just finishing up on the shell side. Another great client: he's a construction law attorney. The crew is finishing up our side of it tomorrow. We will not be doing the siding ourselves, but we did a lot of the interior finishes.

Last project: this is what's in the shop. This is Pratt Road -- that's my road. I built all but two of the houses on Pratt Road. Here's another one, just up the road from us. I'm proud to say it's a very simple, very straightforward house. We started in design three months ago. It's going up now. The budget is $150/square foot and we're going to hit it. Walls in production: this was yesterday. Here's one of our guys injecting the cellulose. We have a pretty sophisticated system, and he can tell you exactly the density that he gets out of it. He's shooting for about 3.4-3.5, and he'll be able to measure that. Here's yesterday: Art's doing the drywall, and Nathan's doing the shingling. They're all working at a very comfortable height, and very quickly.

What's next for us? We have put together a collaboration with This Old House ventures. This is not the show, it's the magazine. We're going to be offering a Bensonwood/This Old House series of homes that are rather traditional. They'll be offered across the country, as prebuilt, prefabricated elements that we will deliver to site.