TIMBER FRAMING

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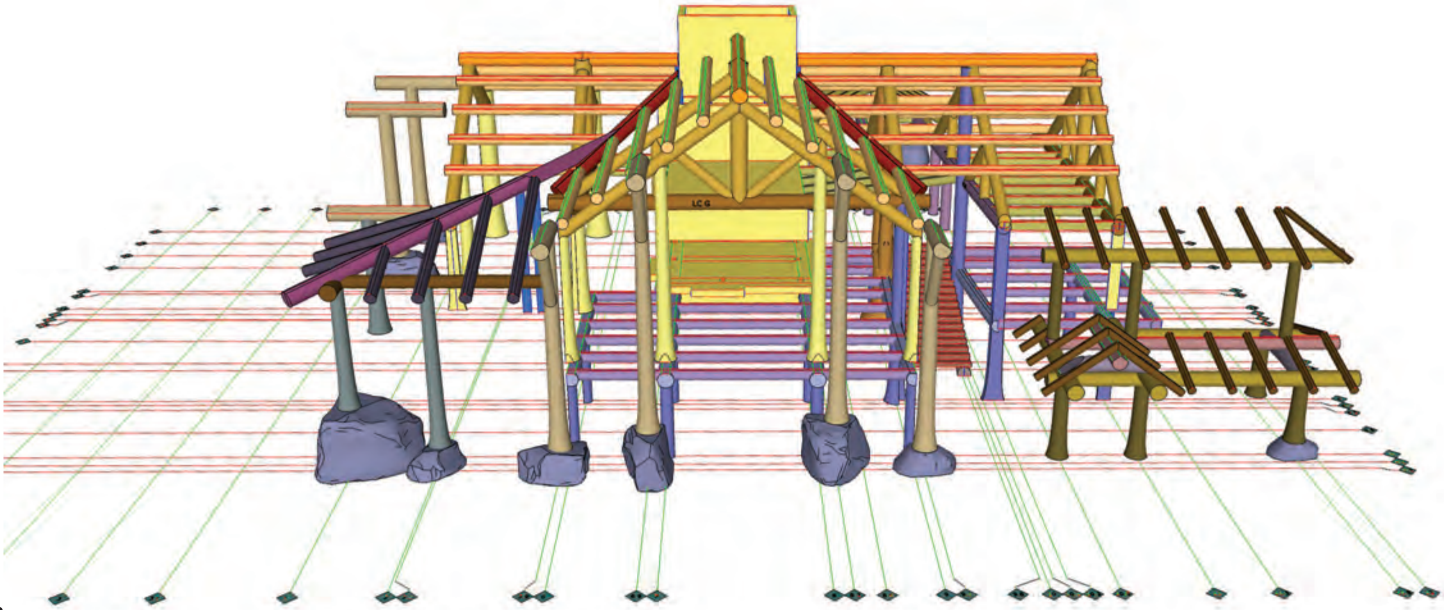
Round Log Timber Framing

Photos John Nininger

1, 2 New Moosilauke Ravine Lodge of Dartmouth College seen from west, frame nearly complete, 2017. Below, winter raising.

Round Log Timber Framing: The Moosilauke Ravine Lodge



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The Wooden House Company

3, 4 Computer model of new Moosilauke Ravine Lodge log frame. Below, John Nininger, left, of The Wooden House Company, and Putnam Blodgett, Dartmouth '53, who supplied much of the timber for the new lodge, stand before the old lodge in its last days.

THE original Moosilauke Ravine Lodge, in North Woodstock, New Hampshire, replaced earlier this year, was built in 1938 for the Dartmouth College Outing Club by a combination of local labor and college students, using old-growth spruce logs cut just up Jobildunk Ravine from the building site.

The 1938 work was carried out under the direction of a single master builder, Ross McKenney, the Club's longtime woodcraft advisor. The enthusiasm that raised the old lodge, a stacked-log building said at one time to be the largest in New Hampshire, sustained it through its 78-year life, with each new class of Dartmouth students adding layers of memories, wear and, not infrequently, creosote.

Originally a ski lodge standing at 2450 ft. on a flank of Dartmouth-owned Mount Moosilauke (4803 ft.), the Ravine Lodge has long figured prominently in the college's first-year student orientation program. The widely felt nostalgia for the original lodge, bordering on veneration in some circles, was impressed deeply upon the designers and builders of the new lodge, respectively Maclay Architects of Waitsfield, Vermont, and John Nininger's Wooden House Company, of Wells River, Vermont, who also participated in the design development.

The architects had been instructed to design the new lodge as a net-zero energy building in support of the college's sustainability efforts, beyond the reach of the traditional full-scribe log building many had hoped for. So, while the new lodge had to look quite a bit different from its predecessor, it still needed to express the same spirit and possess the same nostalgia-inspiring charm of the original, long known for its "rustic mountain accommodations."

The result is a unique log timber frame whose particulars of design and materials demanded continued innovation and refinement of techniques throughout its fabrication (Figs. 1, 3). Achieving the lodge frame provided an opportunity for each member of the crew to push beyond previous technical comfort levels, for long hours outdoors in all seasons, in all weather (Fig. 2).

Beyond delivering the frame on time, two objectives guided our work as builders. First was to maintain the natural full-round form and surfaces of all components. We would preserve the unique character of each log as freshly peeled. Interfaces with the planes of floors, walls, and roof would be the only surfaces milled flat. The second objective was to use solid wood joinery throughout the frame. Using carefully designed drawbored mortise and tenon, wedged and cogged joinery, often in inventive combinations, ensured a durable frame with joinery that would remain as tight as possible over time.

Steel elements deemed necessary for a public building would be hidden in the frame. Structural screws would clamp together bearing surfaces of notched and lapped joinery and tension rods reinforce already substantial joinery in the roof trusses, but steel would not replace solid wood joinery in design. Upholding these objectives would make a substantial contribution to continuing the aesthetic legacy of the original lodge.

All the trees that went into the Ravine Lodge frame were sourced within 40 miles of both the site and our building yard. The high quality and large size of the material, Eastern white pine and Northern white cedar, are a testament to the capabilities of second- and third-growth forests in our part of northern New England. The timber was cruised and marked in the fall of 2015 and winter cut in early 2016. The white pine was found on Dartmouth-owned land in Hanover, New Hampshire, and on the meticulously managed Bradford, Vermont, woodlot of Putnam Blodgett, a 1953 Dartmouth graduate who had been actively involved in the college's affairs on Mount Moosilauke for six decades (Fig. 4).

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Caroline Nininger

Photos Adam Miller

5 Internal corner post supporting two trusses, with valley and purlins above.

6 Tower crane at middle of Wooden House Company yard, Wells River, Vt. Mount Moosilauke visible behind tower.

7 Lofted layout lines clearly visible below frame assembly 61 ft. wide.

8 Portion of peeled logs gathered in the yard. Pine logs are up to 54 ft. long and 30 in. diameter.

9 Preparing cedar post. Note centerline mark corresponding to bulls eye on granite.

10 Tall post (upper member) to girder joinery, accomplished by offsetting centerlines.

Eastern white pine (*Pinus strobus*) was chosen as a primary species for its local availability in large, high-quality stems well suited to the scale of the building, its ease of working and its dimensional stability, an important consideration as we worked with logs up to 30-in. dia. Northern white cedar (*Thuja occidentalis*) was chosen for its rot resistance as well as its dimensional stability, as it would be the primary exterior species, and for its tremendous character, with textured and deeply furrowed stems rising from broad butt flares that would be featured at the base of posts both inside and out (Figs. 1, 5). Where they meet in joinery, the colors of the two species are similar enough not to distract the eye from the form of the frame. Contrast in surface texture between the furrowed cedar and the smooth pine is far more distinct.

Once on the landing, logs were assigned inventory numbers, carefully scaled and graded, and notes made on particular features of individual logs. Resulting inventory spreadsheets played a central role in planning and in selecting frame members.

Logistics and log preparation A tower crane stands at the center of the building yard, allowing for safe, rapid positioning of long, heavy and frequently awkwardly shaped components anywhere within a nearly one-acre area (Fig. 6). A broad, smooth concrete slab within reach of the crane serves as the scribe floor. Substantial additions made to this slab accommodated the nearly 65x100-ft. primary plan layout of the lodge. This full-size plan view served as our guide and standard throughout fabrication (Fig. 7).

Before any layout can begin, bark must be removed from the raw logs. The finished surfaces of the frame are produced at this initial stage. To peel bark cleanly from a log, the bark has to be willing to come off. While the crew was eager to get to work, we had to wait for our winter-cut logs to break dormancy, as if they were still standing in the forest, and thus for the cambium cells to loosen. Spud-wielding log peelers look forward to the glorious moments when bark flows off their leviathan in great sheets, but the work is typically quite a bit more tedious, a lot of careful heavy labor, and protective chaps grow stiff over time with layers of dried pitch. Pressure-washing follows peeling to remove residual cambium. Careful washing techniques were particularly valuable in preparing the higher relief portions of the cedar logs, where spud access was confounded. With nearly 250 whole logs (many of them 40 to 50 ft. long), the debarking process was a major team effort for two and a half months (Fig. 8).

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As the clean stock emerged from debarking and log inventories were updated, we began selecting and preparing particular components. Floor joists were sawn flat on one face, as were roof purlins, which latter also were rabbeted to receive ceiling paneling after enclosure of the building.

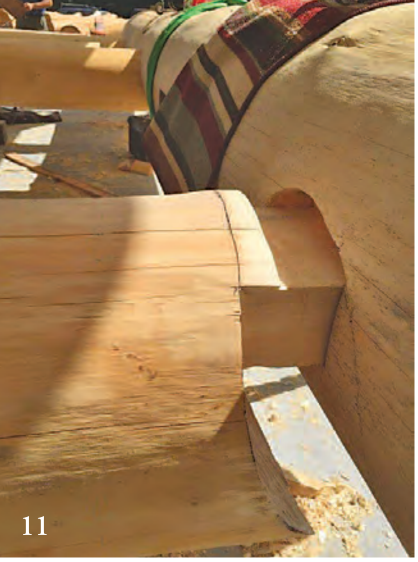
Initial preparation of the cedar posts, marking centerlines and level-cutting their feet, was a more involved process. After consideration of its particular character, the butt of each post was centered over a granite surface plate standing on a set of screwjacks. Laser lines aided in adjusting the jacks to plumb the post at its finished height, and centerline marks were placed on four sides of the post at useful intervals (Fig. 9).

With the centerlines marked, the foot of the post was scribed level to the granite plate to retain as much butt flare as possible. On logs with significant sweep and asymmetric butt flares, just what makes for the most useful set of centerlines is often a compromise, but responding creatively to the biomorphic forms was valuable practice, and led to elegant solutions in demanding situations (Fig. 10).

Lofting the reflected plan view of the frame on the concrete slab set the stage for building all the major assemblies of the lodge frame upside down. This technique, practiced and refined over time, made major contributions to the efficiency and accuracy of our work on the lodge. While the concept of inverted framing may seem odd at first, there is very solid reasoning for its use in log framing. For example, the plane of a floor is defined by milled flat surfaces on otherwise round joists and carrying beams. By building this floor system upside down, the milled future upper surfaces of all its components align at a constant height above the reference plane of the scribe floor. Three-in. mortises are located 6 in. "above" the milled flats, with bearing housings in the receiving girders following the scribed shape of the individual joists (Fig. 11 overleaf) The idea is to take advantage of the flat planes defined by the frame, whether floor, wall or roof planes, to jig the components in proper orientation to one another for scribing, always in reference to the lofted plan layout. Centerlines snapped on the milled flats are easily aligned to the lofted layout lines on the concrete. The rotational position of the logs in an inverted assembly is indexed by the milled flats, a variable we were happy to remove from the mix when adjusting positions.

Joinery By the latter half of August 2017, we began scribing joinery in earnest, beginning with portions of the floor systems (Fig. 12). Here we developed our approach to horizontal bubble scribing, an unusual alternative to conventional vertical bubble scribing (Fig. 13). This low-tech approach proved fast, reliable and highly adaptable to joining floor joists to their varied carrying beams. In a variation on the concept of double-cutting often found in plumb-line scribing, a rough-shouldered tenon would be partially inserted into its completed mortise to a known offset, then its shoulders horizontally bubble scribed. Careful measurements ensured that forming the rough tenon did not remove material needed to produce the completed scribed shoulder. The resulting scribe line is used to lay out the balance of the joinery, including portions of the joist to be coped around the carrying beam and those to be housed into the carrying beam, transitioning at aptly named critical points (Fig. 11).

Taking account of the relative diameters of joined members is a constant concern for both aesthetic proportionality and structural design in round log timber framing. Here in the floor



Photos at left and above, John Nininger

11 Completed joist to girder joint in inverted floor assembly. Lines from horizontal bubble scribing visible on both members.

12 Nearly completed three-bay inverted floor assembly.

13 Horizontal bubble scribing setup. Pens remain properly aligned no matter how rotated.

14 First-floor lifting wedge detail to keep wood framing level with steel framing outside our scope of work (visible in background).

Adam Miller

system, too small a joist could make the carrying beam appear excessive, while the underside of too large a joist could not be sufficiently supported, as the housing in the supporting beam would become too fragile to bear load and interfere with material required for a properly drawbored peg hole. Fairly heavy drawbore is key to producing tight, seamless transitions between members. With shoulders significantly dished (hollowed) across their width, their sharp edges compress into mating surfaces when drawn up, evening out any minor variations in the scribe line.

The significantly smaller scribe settings made possible by the horizontal double-cut approach offered an advantage in accuracy over vertical bubble scribing. Horizontal scribe settings of 4 to 6 in. replaced vertical scribe settings in the 14-in. to 16-in. range.

Responding to concerns of the project architect and engineer, we incorporated a system of 4-in.-wide red oak lifting wedges into all the posts supporting the first floor of the frame to compensate for any shrinkage in the 20-in.-plus-dia. girders, in order to maintain the level of the first floor, which included steel and engineered lumber in areas outside our scope of work. Nonbearing portions of the post tops are housed into the girders deeply enough to accommodate any possible advancement of the wedges, which themselves are scribed to fit the underside of the girders (Fig. 14).

Post G6 (Figs. 5, 15) is a good example of how the biomorphic forms of our materials drove the development of specific joinery. The largest-diameter cedar log in the building, G6 supports two perpendicular trusses. As the tie beams of the trusses sit at different heights and each continues past their intersection, the post needs to pass across the lower truss to support the upper one (Fig. 5). Offsetting the post centerline from that of the lower truss, in combination with a large tapered housing through the side of the lower tie beam, allowed enough of the post to pass through to support the upper truss (Fig. 17).

The tapered housing also partially compensated for the extreme recurve configuration resulting as the post continued up past the maximum breadth of the lower tie beam. Dealing with the balance of the recurve required riving off material from the post that would otherwise interfere with its assembly with the lower truss—riving with a view toward later reattaching the material invisibly after assembly (Fig. 18). The rived material was indeed reattached during first assembly and scribed to the upper truss along with rest of the post. The result is a nearly seamless display of interpenetrating logs that hides pegged mortise and tenon joints inside (Fig. 16).

Roof structure Mortise and tenon joints at an appropriate scale and with scribed shoulders support the lodge's principal rafters, whether part of a functioning truss, a posted truss or a large multi-story frame. Rafters terminate in their tie beams with twinned 3-in.-thick tenons in 10-in.-deep mortises.

Abutments bear perpendicular to the bisected roof pitch angle. Rafters join to kingposts with a single 6-in.-thick tenon. Toward the midspan of the rafters, princeposts and struts were first horizontally scribed together, then scribed to the rafter as a unit, tenons sharing a common mortise but pegged individually (Fig. 19).

At the complex meeting of kingpost and struts to tie beam on two of the trusses, mitered joinery indexed to position with stub tenons engaging keyways makes the connections. In this approach, optimized miter angles are developed on the scribe floor based on actual diameters of the individual components.

Mitered joinery has the potential to expedite fabrication of such complex interactions while producing large flat bearing surfaces, but it does require some reshaping of the component pieces to match cleanly (see front cover)—the one connection in the frame at odds with our objective to keep the logs in their natural form.

All structural reinforcement required in the roof system is completely hidden and consists primarily of 1-in.-dia. steel rods anchored in 2-in.-dia. steel barrel nuts—cross-dowels pierced by transverse threaded holes (Fig. 20). The barrel nuts provide robust

Photos above, at top and top right Adam Miller

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but unobtrusive anchor points in visually sensitive interior locations, and installation holes can be easily plugged. Rods are tensioned against bearing plates on exterior surfaces invisible in the finished building. By using multiple grades of steel for the rods and nuts, we were able to meet varying reinforcement capacity requirements with a single set of tooling.

At the eaves of the frame's gable ends was a challenging rafter-to-post connection. The solution, which we came to call the T-Bone joint, was a

15 Post G6, internal corner post, set up for initial scribing on three screw jacks for stability and fine adjustment.

16 Detail of post assembled (see Fig. 5 for full view), with 2-in. holes in truss tie beams to house steel barrel nuts.

17 Post housed through tie of lower truss. Cutaway in tie is continuation of earlier cut in post made for internal corner of building.

18 Author and completed post with (temporarily) reattached filler pieces.

19 Combined princepost and strut for entry to common mortise.

20 Threaded 1-in. tension rod and 2-in.-dia barrel nut.

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vertically cogged post top tenon that extends through the full height of the rafter (Fig. 21).

Since in the nature of scribed work, and of this uniquely complicated frame, we would put together and take apart the joint more than once, the surfaces are tapered in two directions, drawing up tight only in the last few inches.

We used T-shaped cogs and notches in numerous other locations in the lodge frame for similar reasons.

With different phases of work happening concurrently, a crew of four from nearby Timberhomes LLC, in Vershire, Vermont, joined us for a month in the fall. Timberhomes had been responsible for building numerous bunk houses on the Ravine Lodge campus and on this occasion helped us to complete the main floor system, freeing up the Wooden House crew to focus on roof trusses. A structurally independent exterior porch was later contracted out to Timberhomes LLC.

The roof system was the single largest assembly of the project. The roof rack, a large scaffold representing the inverted shape of the roof planes, was key to the process (Fig. 22).

Scribing the roof system inverted over the same plan layout used throughout each prior stage of fabrication offered the best possible approach for accuracy of fit. The purlins' rabbets registered on blocking built into the roof rack, easily aligning them in plan and in relation to the roof plane. Building the roof upside down also kept the assembly close to the ground, as numerous posts extending below the plate height were integral to the roof system, and it was good to have the ridge logs as structural ties at the base of the scribe assembly since there were no plates that could perform similarly. Once the ridges and purlins were in position, the two valley logs were set up to be scribed down onto the purlins.

Vertical bubble scribing was the rule in the roof assembly. The joinery here consisted of fully diminished 3-in.-deep housings with square shoulders cut into the valleys. Purlin ends cut to bear in the housing were secured in place by ¾-in. steel rods, a connection chosen to fully draw up the joint while maintaining ease of disassembly.

The heaviest of the trusses, at nearly 8000 lbs., tested the lifting limits of the crane, fully vindicating the decision made almost a year earlier to expand the concrete slab. Once precisely levelled and positioned, which took screw-jacks, laser levels, wedges and braces in varied creative combinations, the trusses and principal rafters were vertically scribed down onto the purlins and valley rafters with a scribe setting consistent across each pair of rafters. Rafter pairs not part of assembled trusses were provided with false tie beams to maintain proper alignment while positioned as a unit.

Scribing the roof assembly in an upright orientation would have begun with setting roof trusses and rafter pairs over a lofted layout. Posts integral to some of the trusses would have required the entire assembly to be elevated, with a theoretical plate height (there are no actual plates at the eaves) of approximately 15 ft., placing the working height for the assembly approximately 30 ft. above the concrete, creating difficulties of working efficiency and safe access. Next, the very large ridge logs, positioned almost 35 ft. in the air, would have to be scribed down into the peaks of the trusses and rafters. The valley logs would then be scribed down into the rafters. Following this, purlins would need to be individually positioned and indexed to the roof plane above the level of the valleys before being scribed down to both rafters and valleys, requiring very large vertical scribe settings on scores of joints. Given the particulars of this project, scribing the roof system as an inverted assembly offered improved accuracy in positioning components, reduced the number of components that needed to be positioned individually and offered greatly improved safety and ease of access by significantly lowering the working heights in the assembly.

The purlin-to-rafter joint was detailed as a square notch, where large tabling defined during scribing divides section loss between the two members and self-aligns the position of the purlin vertically, laterally and relative to the roof plane, a combination that really pays off at raising time and maintains apparent tightness of the joinery as the logs dry (Fig. 23).

With the frame completed inside the building envelope, focus shifted to exterior assemblies: a pair of porches, an entryway, two series of gable overhang brackets, a large flat-roofed woodshed and a pavilion to be located at a distance from the lodge.

Notably, though, one set of gable brackets incorporated knee braces (Fig. 1), an element conspicuously absent throughout the rest of the frame, where engineered shear walls took their place. The broad, tightly fitting shoulders of hundreds of joints, however, combined to provide an underappreciated amount of stability to the frame.

Raising The Ravine Lodge frame was raised in three principal phases from January to March of 2017. The demanding site, as noted at the beginning of the article, lies at nearly 2500 ft. in a steep mountain ravine in northern New Hampshire. Topography limited crane access to a few locations on the downhill side of the building, and frame components could only be delivered a single tractor trailer load at a time, backed up a narrow access drive, making transport logistics a significant concern in the raising plan. With a complex frame to raise in any circumstances, our task was further affected by the compressed overall construction schedule, with numerous trades operating on site concurrently.

The first principal phase of the raising included installing the main floor system and the bent frames defining the stair bay, whose multistory posts were integral to the floor system (see back cover).

Several weeks later, following a major effort by the on-site stick-framing crew, we returned to install the balance of the interior frame. In the final principal phase of raising, porches and gable brackets were installed.

Additional smaller raising phases carried on periodically through the spring months, installing the woodshed, front entryway and staircase (Fig. 24).

Delivery of a log-posted pavilion at the head of the lodge access trail (Fig. 25) marked the completion of our long journey to create a unique new structure inspired by its memorable predecessor.

—Adam Miller

Adam Miller (rangeradammiller@gmail.com), an independent timber framer, devoted more than a year at The Wooden House Company (woodenhousecompany.com) to seeing the new Moosilauke Ravine Lodge through from start to finish, and recently led fabrication of the Jack Sobon–designed Mountaintop Arboretum frame for Uncarved Block, Inc. (uncarvedblockinc.com). When at home, he can be found in Newbury, Vermont.

The Moosilauke Ravine Lodge, by the Numbers
Compiled by John Nininger

15,000 total hours of labor
12 months of active work
50,000 board feet of logs used, by sawlog scale
5,000 linear feet of logs used
250 trees
462 log components
900 total joints
Longest finished log: 48 ft.
Crew size: 4–10


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Above and below, Adam Miller

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21 End view of disassembled T-Bone joint.

22 Loading the roof rack with purlins.

23 Square notches between porch plate and rafters.

24 Staircase and boulder in finished building.

25 Trailhead pavilion, with Mount Moosilauke visible across Jobildunk Ravine.