3 PART SERIES

PART I

Building Owl Observatory

Tired of lugging your telescope around and observing in the cold? Build a well-designed observatory and explore the sky in comfort.

Story and photos by Jim Krick

Not long after the purchase of my telescope, I thought about how great it would be to have my own observatory. During the next six years, I made a list of the problems I encountered when observing in order to determine what would be best for my observatory design. Several years of cold feet, numbing winter wind, dropped set screws, kicked tripods, broken cables, and dead car batteries taught me what I really wanted.

To get a better idea about how to solve my problems, I looked through ASTRONOMY magazine and read *How to Build Your Own Observatory* (which contains reprints from *Telescope Making* magazine). I wanted an efficient, easily manageable, and comfortable structure that would fulfill all of my needs. No single observatory described in these magazine articles seemed just right for me, but I did pick up some ideas. Still, I had to choose between a roll-off roof and a dome and between a concrete and a wooden floor. And where to build my observatory — in my backyard or out of town, away from the lights? What about my abilities as a builder? I am not a professional carpenter, just an average do-it-yourselfer. My observatory would have to be built with powered hand tools, including a saw, a small miter saw, a scroll saw, a couple of drills, and a borrowed router.

This article will show you how I solved these problems and built the foundation for my observatory. Two later articles describe how I built the floor, walls, and roof. The observatory cost only $1,500 and was a wonderful project.

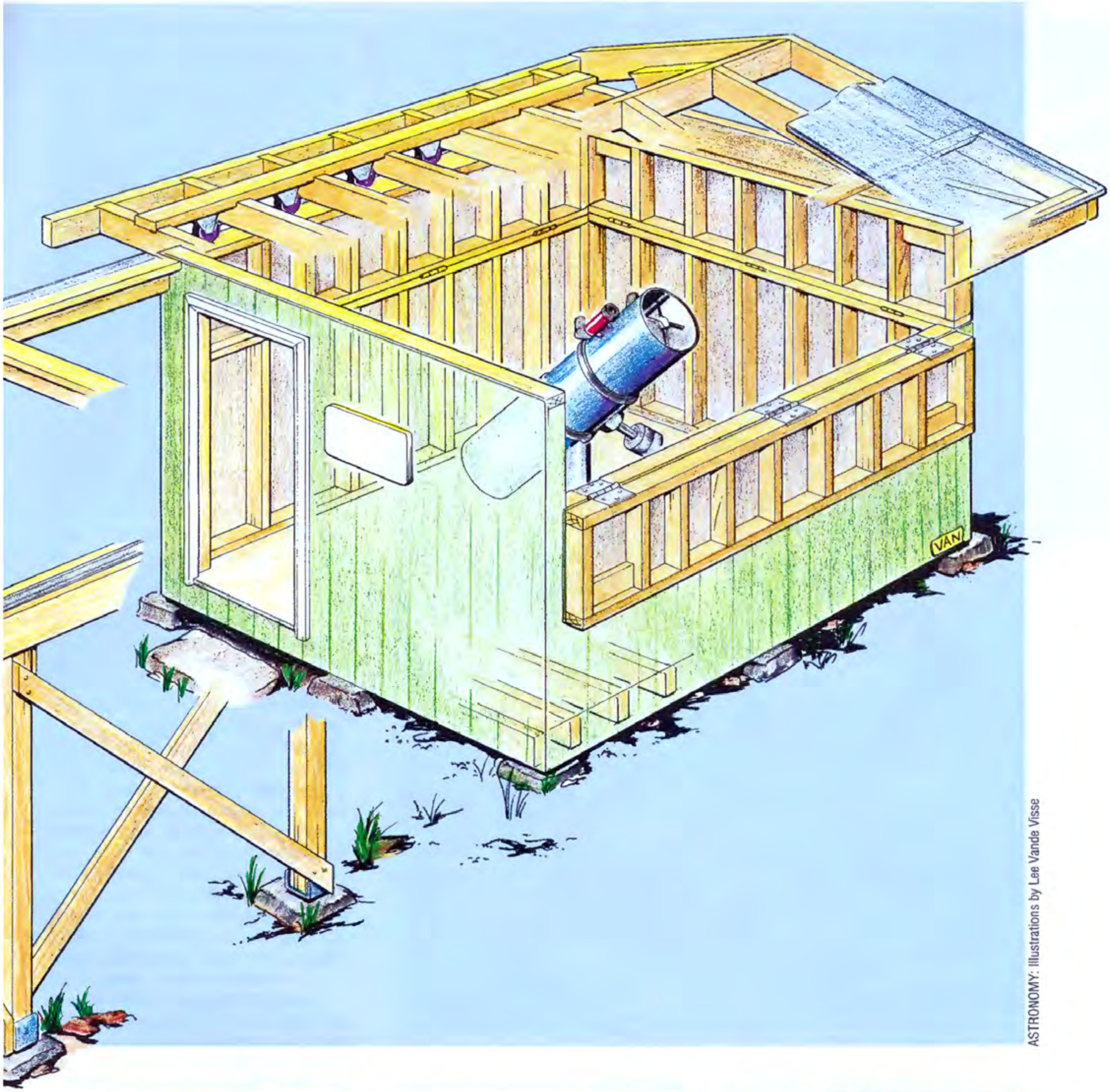
(Note: Before you build a observatory, check with your local building inspector to determine whether you need a permit and what building restrictions may apply to your structure.)

Designing Owl Observatory

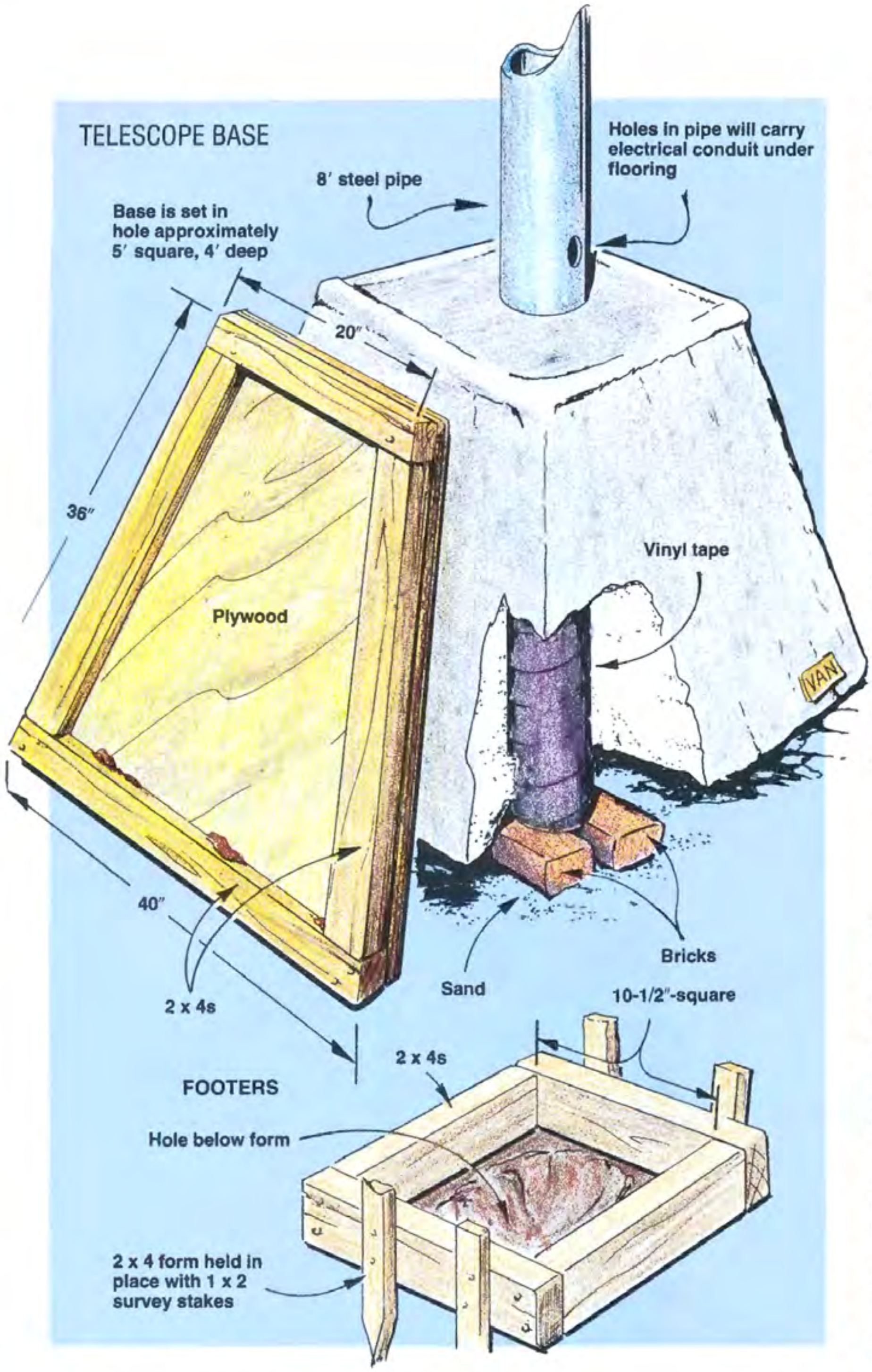
I live in Great Falls, Montana, which is located in the central part of the state and has a population of about 50,000. Light pollution in town is unacceptable, and too much of the sky is obstructed by trees and buildings in my backyard. So I decided to build out of town where there are dark skies and a clear horizon.

For the past few years I have

THE ROOF ROLLS OFF to the north and the walls fold down to permit access to the night sky (center right), yet they close tightly to seal out the elements (right). The observatory is a great place for family outings (far right).



ASTRONOMY: Illustrations by Lee Vande Visse



THE STEEL TELESCOPE PIER is set in a pyramid-shaped mass of concrete. The pipe sticks out of the bottom of the concrete to prevent condensation.

packed my scope in my truck and driven to an abandoned farm about 25 miles east of Great Falls near the small community of Highwood. This old homestead has a weathered windmill and a small reservoir and is surrounded by fields of wheat and barley. This site is not only ideal for observing and astrophotography, but abundant wildlife and the nearby scenic Highwood Mountains make my outings an enjoyable and relaxing experience.

The property is owned by Earl Davison, who is a farmer, rancher, and friend. Earl agreed to meet me at the site and discuss my plans for an observatory. A few hours later my dream began to become a reality when Earl agreed to lease some land and I could start to build my observatory.

Although I am not an architect by any stretch of the imagination, I think my plan is a good one. As an astrophotographer, I want clear access to the entire sky. I felt the view of the sky through a dome was too restrictive. So I chose to build a roll-off roof, which would also save on cost. For greater access to the horizon, the top two feet of the east, south, and west walls fold down. The entrance is in the north wall and the roof rolls off to the north, so there is no point in having this wall fold down. The telescope is mounted on a steel pipe set in concrete. And the wood floor is raised, which helps to keep my feet warm in the winter.

The building is 10' square, providing ample room for the telescope, with room left over for a table to hold charts and extra equipment. The rails for the roll-off roof make the overall structure 10 x 20 feet.

The work progressed in three phases. Phase one was the construction of the pier and building foundations. This was done during the summer and fall of 1990. Phase two included building the floor and walls. This work was started during the winter in my garage and finished at the site in the spring and summer of 1991. The final stage was building the roof. This enclosed the observatory before the winter of 1991 struck.

PHASE ONE
The Pier

It is easier to cast the pier first and then cast the building footings. This order of events ensures that the building will be centered on the pier. My pier consists of an 8" steel pipe set in a pyramid-shaped concrete footing. The pyramid shape gives the footing a low center of gravity, which should help prevent shifting in the ground.

In any case, a pier means digging a hole in the ground. Dig a hole much larger than you need for the footing so you'll have room to install and remove the forms used for pouring the concrete. My footing measures 40" square at the bottom, 20" square at the top, and 3' high. My son Josh and I dug a hole 5' square and 4' deep. It took us over four hours to dig the hole by hand.

For the sides of the form, I cut four trapezoid-shaped pieces from 1/2-inch exterior grade (CDX) plywood (see the illustration above). I then reinforced the plywood with 2x4s along the top, bottom, and each side. Everything was fastened with screws. Building forms to hold about a yard of concrete is one place where you want to make everything as strong as possible.

New pipe is expensive, but you can go to a junk yard or scrap metal dealer and buy used pipe. I was lucky to be given an 8' length of used pipe. I bought a scrap piece of quarter-inch plate steel and welded it to the pipe for use as an accessory

THE HOLE FOR THE PIER is dug to a depth of four feet. Then the pipe wrapped in vinyl tape is set plumb and held in place with stakes and 2x4s (above). The eyepiece shelf and hole for the electrical conduit are visible at the top of the pipe.

AFTER THE CONCRETE SETS, the forms may be removed (above) and the hole backfilled with dirt (left). Replace only about six inches of dirt at a time and tamp it firmly to prevent the pier from settling later.

shelf. Several $1^{1}/_{4}$-inch holes drilled in the plate will hold eyepieces during my observing sessions. Not everyone has welding equipment or the tools necessary to drill holes in plate steel, but you can go to a local machine shop to have this work done for you.

Toward the top of the pier, I drilled a hole for conduit to run into an attached electrical outlet box and a second hole where the conduit exits the pier under the floor. At that time, I didn't know when I would get electrical power installed at the observatory site, but holes couldn't be drilled in the pier once it was installed. In the meantime, I could use the conduit with a DC battery and never again worry about tripping over power cords.

Before setting the pipe into the ground, I coated the lower four feet of the pipe — the part to be underground — with a quick-drying tar and then wrapped it with vinyl tape. (This technique is used in gas construction to prevent corrosion of steel gas lines.)

Now to set my pier and forms. The pier should extend through the bottom of the footing to allow any condensation that forms to drain away and, thus, prevent rust and corrosion. I did this by digging a 6" deep, 18" square hole in the bottom of the pier hole. I put two bricks in the center of this small hole and placed my pier on top of them. The pier was supported across the top of the big hole by 2x4s, which in turn were screwed to stakes that were driven in the ground (photo above). I could plumb the pier easily by moving the end that was resting on the bricks. Once the pier was plumb, the small hole was filled with gravel. The gravel helps to keep the pier in place while pouring the concrete and insures that the pier will extend out the bottom of the footing afterward.

The forms were installed one at a time around the pier and screwed together. After centering the forms around the pier and leveling them, I drove stakes into the ground around the bottom of the forms and screwed them to the forms. Use at least three stakes on each side, because concrete has a tendency to lift the forms and push out through the bottom.

When pouring concrete, don't forget to put in reinforcing bar. Also called rebar, it strengthens the footing and holds it together if it develops cracks. Since it's nearly impossible to pour such a large volume of concrete and not have some cracking, it's a good idea to install rebar.

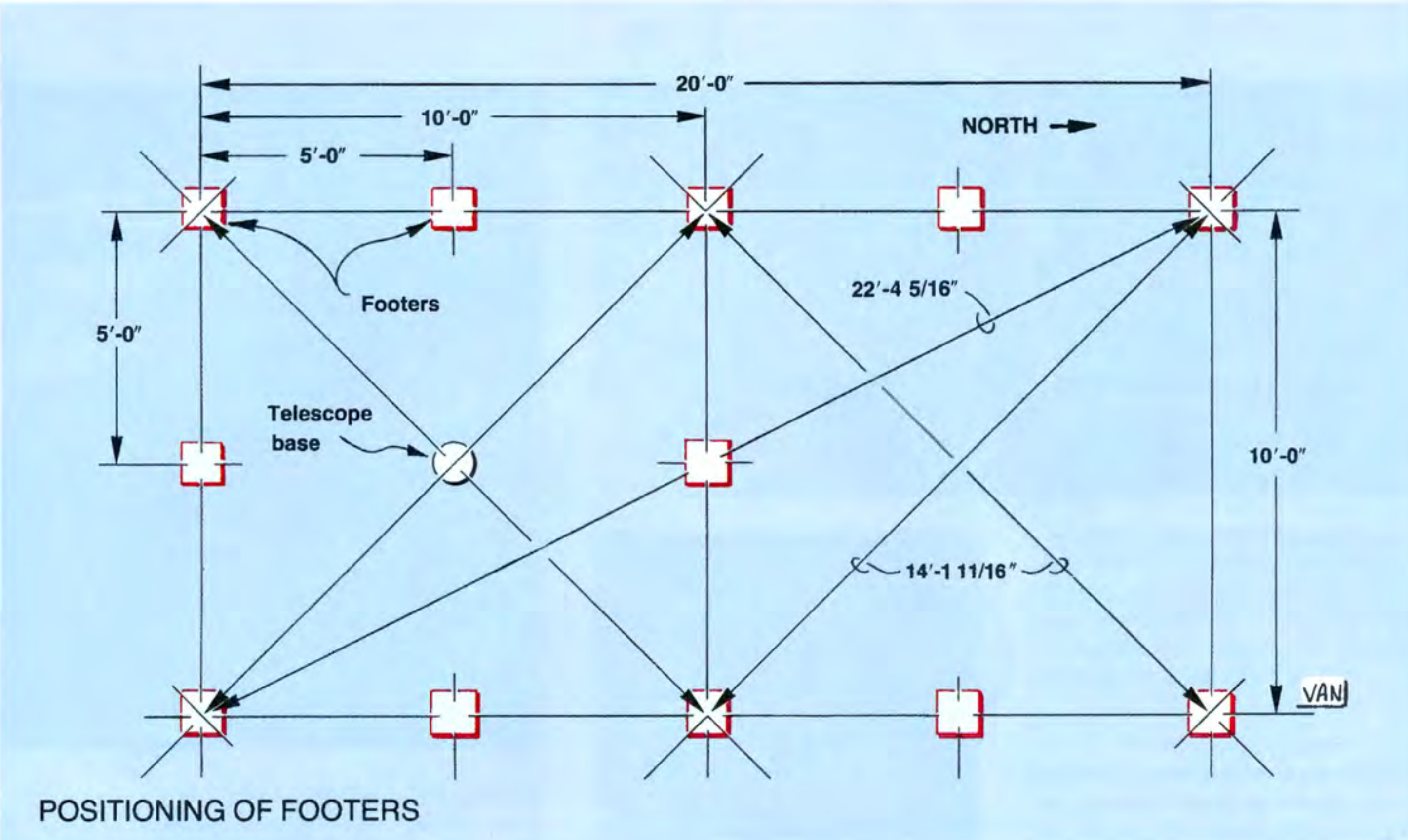
I needed a little under one yard of concrete to pour the footing for my pier. Locally, delivered concrete costs $65 a yard. But there was one string attached. Since the job site was outside the city limits, a $95 delivery charge would be added to the cost of the concrete. I decided instead to mix and pour my own concrete. (In some areas, you can borrow or rent a small trailer to haul ready-mix concrete instead of having it delivered by truck.)

One evening I hauled about a cubic yard of mixed sand and gravel in a rented trailer. The following evening Josh and I took a rented gas-powered cement mixer, five bags of cement, and thirty gallons of water out to the site. We mixed the concrete following a one part cement to three parts sand and gravel recipe. The normal mixture is one to five, but I wanted a stronger-than-normal pier footing. About a week later I removed the forms. The cost of the materials and rentals came to $90. And I had enough material to complete the footings for the building.

I filled in the remainder of the hole with the dirt from the excavation, shoveling in only about six inches at a time. To eliminate later settling of the pier, I thoroughly tamped each layer. I raked the leftover dirt level to prepare for construction of the building footings.

The Foundation

While designing my observatory, a major concern was the longevity of the structure. I wanted one that would last my lifetime. I did not



TWELVE FOOTINGS FORM THE FOUNDATION. Using the dimensions from the plan at top, stakes were first driven at the corners of the structure (above). To locate the holes for the footings, batterboards and strings were placed outside the stakes.

want the structure lying on the ground because the wood had rotted. So my observatory has a raised floor. Also, mice are plentiful in this neck of the woods. I don't want to walk into my observatory some night and have it smell like a barn or a grainbin. Few mice will nest under the raised floor. Any that do probably will be cleaned out by varmints — I hope I don't show up some night with a skunk under my feet!

To support the raised wooden floor and the posts for the roll-off roof rails, I set metal post brackets into concrete footings. Eight footings were needed for my 10-foot square building and four more for the rail posts (see the illustration above). I considered using preformed concrete footings available from hardware stores, but they are expensive. Besides I already had all of the supplies necessary for casting my own, left over from making the pier.

Laying out the foundation is one of the most important parts of this whole project. If the foundation is not level and square, you're in for a big headache because it will be hard to build the walls, and the roll-off roof may not work properly. Take your time to get your foundation laid out right.

Laying out a foundation requires only a compass, strings, levels, two tape measures, wooden stakes, and a little high school math. (You can use a transit if you know how to use one or have a friend who does.) First, I ran a 15' string along the east-west direction tangent to the south side of the pier's steel pipe. Five feet on each side from where this string touches the pier, I ran 25' strings in the north-south direction. The strings should extend roughly 7' south of the east-west string. Stakes made from 2x4s driven into the ground near the ends of the strings held them taut. (A nail pounded into the top of the stake will make it easier to adjust the strings.) Next, I marked the corners of the foundation.

I started by laying out the northwest and southwest corners, driving a stake to mark the location of each corner. The southwest corner is 5' south of the east-west string and the northwest corner is 15' north of the string. (To center the pier exactly in your building, subtract the radius of your pipe from the southwest corner distance and add it to the northwest corner distance.) I double-checked that the stakes were exactly 20' from nail to nail and then removed all the strings used to this point to reduce later confusion.

Next, the northeast stake. It has to be perpendicular to the west side of the building defined by the two newly installed corner stakes. You could use a compass to lay out this stake, but that isn't very accurate. Instead I used the diagonal measurement of the building. The diagonal may be found from the Pythagorean theorem — the square of the diagonal is equal to the sum of the squares of the north and west sides. For my building the diagonal is 22'-4 5/16" (the square root of 500, or 20x20 + 10x10).

From the northwest stake, I measured 10' to the east. Using a second tape, I simultaneously measured from the southwest stake 22'-4 5/16" to the northeast. I drove a stake — and nail — to mark where these two measurements intersected. The southeast corner was marked in the same way, 10' to the east of the southwest stake and 22'-4 5/16" to the southeast from the northwest stake. Double-check these two diagonal measurements to be sure that the foundation will be square.

Once the four stakes were set and square, I placed the batterboards that will actually hold the strings used to lay out the footings. The corner stakes must be removed to excavate the holes for the footings. Yet once the holes are dug, we still need the strings to help us set the post brackets accurately in the footings. Place batterboards outside the planned foundation; they are ideal for holding the strings.

To make a batterboard, screw a short piece of wood to the top of two stakes. You'll need to make eight of these, two for each corner. I drove one batterboard into the ground about two feet from the corner stake on each of the outside directions. For example, for the southwest stake, I placed one batterboard two feet south of the corner stake and a second batterboard two feet to the west of the stake (see photo on the opposite page). Once you've driven all of the batterboards into the ground, run four strings (one for each side) so they just touch the nails on the corner stakes. Pound nails into the wood strip of the batterboard to hold the string in place.

You'll need two more sets of batterboards. One divides the foundation into two 10 by 10 foot squares. Place this set of batterboards so their centers are about 10' from the northern string. The position of the dividing line is best measured using diagonals. The southern square has the pier obstructing its center so it is easier to measure from the northern corners. I measured 14'-1 11/16" from these corners to the side strings and marked these intersections with a string running between the batterboards.

AT THE END OF THE FIRST PHASE OF CONSTRUCTION, the concrete footings and pier have been cast and the observatory site has been raked level in preparation for the construction of the floor and walls.

Place the last set of batterboards with their centers about 5' from the northern string. These boards mark the location of the second pair of posts for the roll-off roof rails. I used diagonals from the northern corners of length 11'-2 3/16" to mark the position of this string.

As the final step of the layout, I marked the midpoints in each side of the southern square. Since the square is 10' on a side, I tied a short piece of string onto each string 5' from each corner. The intersections of the strings and knots in the southern square should mark the positions for 12 footings. Finally, I double-checked all the string measurements and leveled the strings.

For each footing, I dug a hole 10 1/2" square and 10" deep. The hole was centered at each point marked by the strings. After digging the hole, I tamped the bottom so the footing won't settle later. The top of the form was made from 2x4s. I drove stakes into the ground around the form and screwed them to the 2x4s.

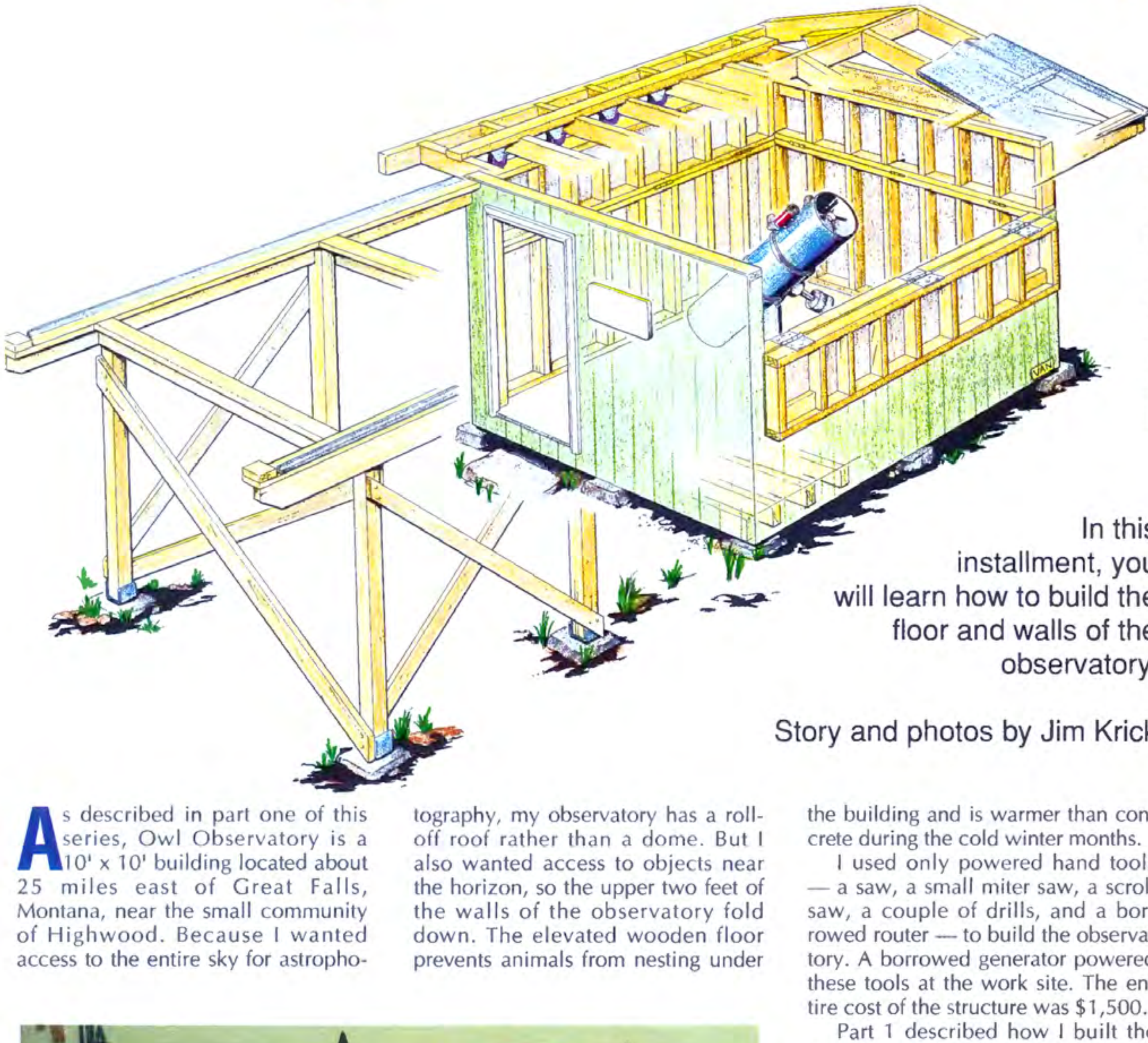
I placed in each hole stirrup-shaped post supports available from the hardware store. The supports have 12" sections of 3/4-inch pipe welded to the bottom. This wasn't long enough so I inserted some 1/2" pipe to get a total length of 18". The extra length of pipe enabled me to drive the pipe into the ground to hold it in place in the center of the form. Each post support was first centered under its string marker and leveled. Then I drove the supports into the ground until they were a uniform distance below the string. The distance from the string will depend on the height of your batterboards, but I set the bottom of my post brackets 4" above the ground.

When all the forms and post brackets were in place, I rechecked the brackets to see that they were level and at the same height. I mixed the concrete by hand in a wheelbarrow and poured the pads. Between wheelbarrow loads, I edged and finished previously poured footings. It took a good day's work to lay out the foundation, dig the holes, and pour the concrete. A few days later I removed the forms, cleaned up the area, and raked and leveled the dirt left over from the excavations.

At this point, phase one was finished. With winter coming on, work stopped at the observatory site. During the long winter months, I prefabricated the observatory walls in my garage. In our next installment, I'll tell you how I built the floor and walls. □

Part two of Jim Krick's "Building Owl Observatory" will appear in the May issue and part three in the June issue.

Building Owl Observatory



ASTRONOMY: All illustrations by Lee Vande Visse

In this installment, you will learn how to build the floor and walls of the observatory.

Story and photos by Jim Krick

As described in part one of this series, Owl Observatory is a 10' x 10' building located about 25 miles east of Great Falls, Montana, near the small community of Highwood. Because I wanted access to the entire sky for astrophotography, my observatory has a roll-off roof rather than a dome. But I also wanted access to objects near the horizon, so the upper two feet of the walls of the observatory fold down. The elevated wooden floor prevents animals from nesting under the building and is warmer than concrete during the cold winter months.

I used only powered hand tools — a saw, a small miter saw, a scroll saw, a couple of drills, and a borrowed router — to build the observatory. A borrowed generator powered these tools at the work site. The entire cost of the structure was $1,500.

Part 1 described how I built the steel pier for the telescope and its concrete footing. It also described how to lay out the foundation for the building and roof supports and how to pour the concrete footings. Because this phase of the construction ended as winter approached, I had to stop construction at the site. But work didn't stop. I prefabricated the walls and roof in my garage.

PREFABRICATING THE WALLS in my garage during the winter made construction go faster and easier. The studs were secured to the top and bottom wall plates with 3" screws.

In this installment, I'll tell you how to build the floor and walls and erect the walls on site. First we'll look at the floor construction.

Building the Floor

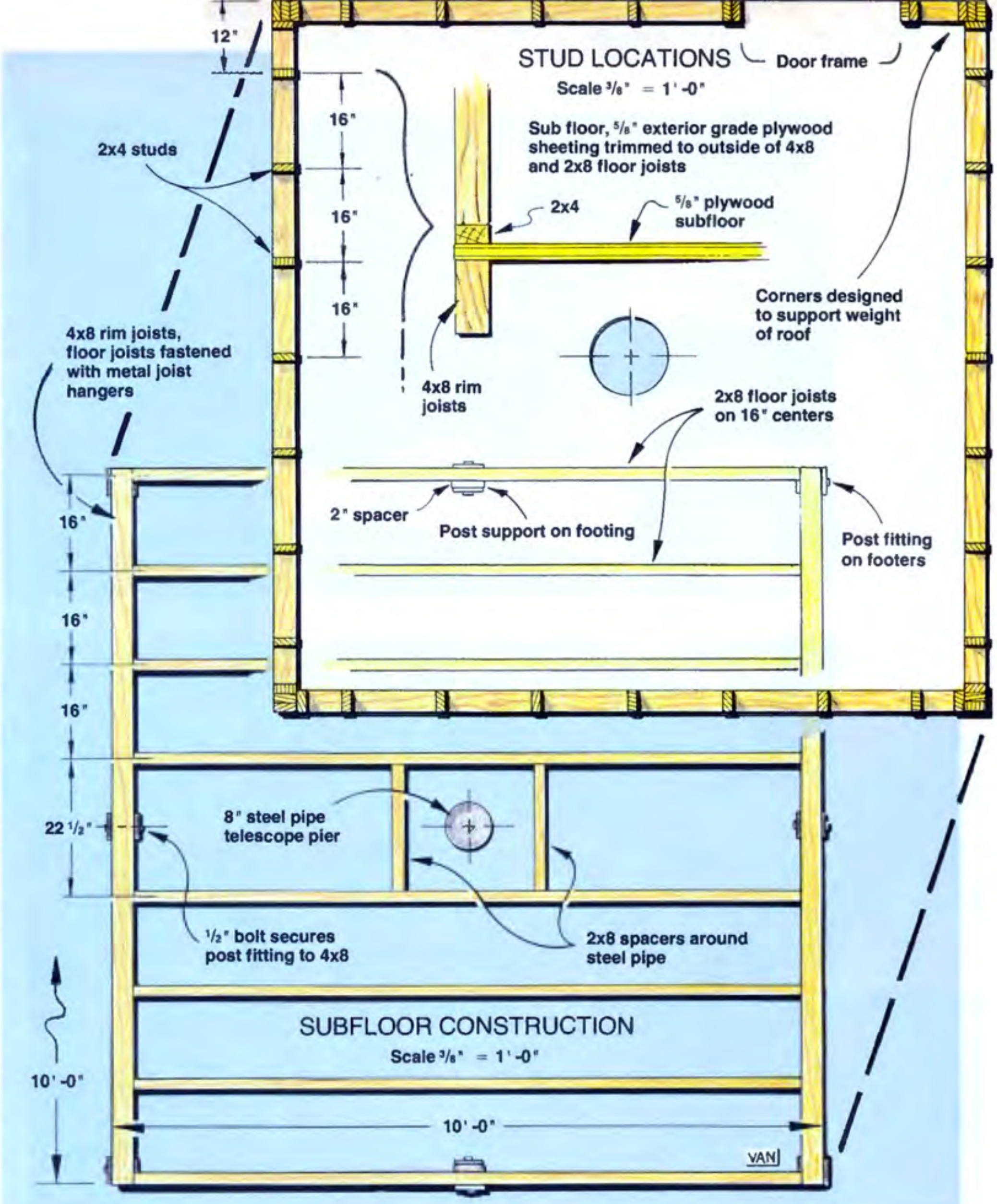
My floor is built over a series of joists that are suspended above the ground by the post brackets set in the footings. The two main rim joists run north-south (see illustration at right). These 4x8 timbers rest directly in the post brackets with 1/2" bolts securing them. If you can't get 4x8s, use two 2x8s nailed together and a 1/2" spacer to hold them securely in the post bracket. I used 2x8s for the floor joists, including the east-west perimeter joists. These joists fit into the post brackets with a 2" spacer. I cut my spacers from 4x4 lumber.

Using metal hangers available from hardware stores, I attached the 2x8 floor joists to the north-south rim joists. I started at the ends of the rim joists and placed the remaining joists on 16" centers. (You may wish to cheat a little on the spacing of the third joist to make it easier to install the subflooring. Move it about 1/2" outwards.) The joists closest to the pier will end up on roughly 22 1/2" centers, which is okay if you use at least 5/8" plywood for the subflooring.

Because the east-west perimeter joists go on the very end of the rim joists, the normal metal hanger doesn't work properly. You can ask your hardware dealer for right-angle brackets that go on just one side of the joist. Alternatively, you could toe-nail the joist to the rim joist.

It is nearly impossible to wire the telescope pier once the subflooring is installed, so take a short break from the floor carpentry and put on your electrician's hat. Run wire through the pier into the conduit that goes between the joists to the future location of the service entrance box. The wires should be enclosed in conduit to prevent animals from gnawing through the insulation. Luckily, working with some of the newer plastics is easier than with the old thick-wall metal variety. Be sure your electrical service is protected by ground-fault circuit interruption (also known as GFCI).

The subflooring is plywood and I attached it directly over the joists. I used 5/8" CDX (inexpensive exterior grade) plywood because I expected to lay particle board as a floor underlayment over this subflooring material. You can use the plywood directly as the floor material, for which you need to use 1" plywood. In this case, you may wish to use a higher grade



THE FLOOR IS FRAMED with 2x8 joists on 16" centers fastened to 4x8 rim joists on the west and east walls (above). The perimeter joists are bolted to the post supports cast in the concrete footings. Bridging is installed around the pier to help support the 5/8" plywood subfloor.

RAISING THE WALLS is easy once the prefabricated sections are delivered to the site (top). The north wall is erected first and held in place with a temporary support. The west and east walls are fastened to the north wall (middle). Finally, the south wall is screwed in place (bottom).

of plywood (AC) for a smoother floor finish.

Laying a plywood floor is easy. Just be sure that the edge of the plywood lies over a joist. Sixteen-inch centers for the joists make this easy. You can find 4' x 10' sheets of plywood, but more commonly you will find 4' x 8' sheets. Because the floor is 10' x 10', you will need to cut several 2' sections to piece in the rest of the floor. In this case, stagger your joints to make the floor stronger, and place factory edge to factory edge to make a tighter joint. Nail (8d) or screw (2" long) the plywood to the joists about every 6".

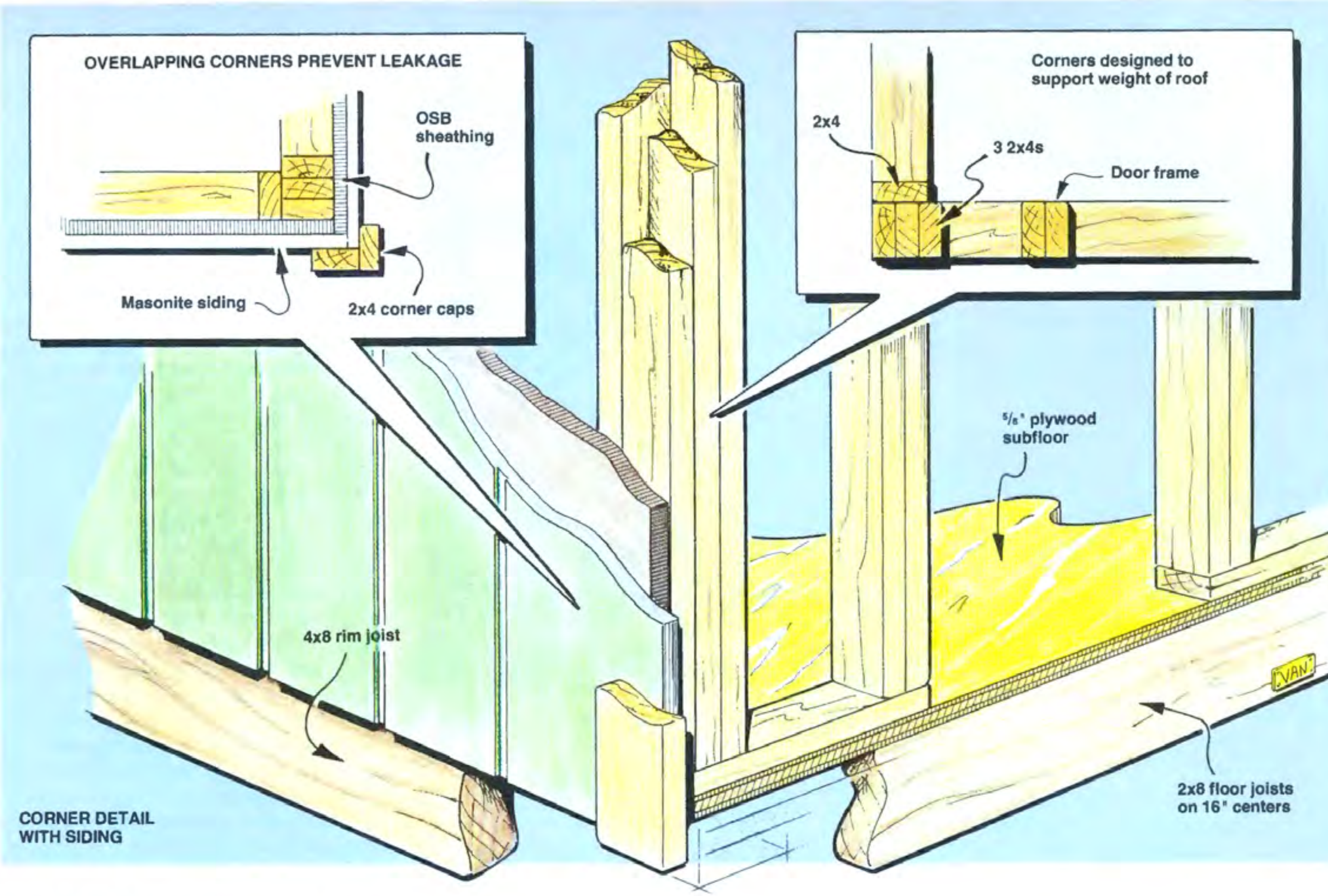
Whatever size plywood you are using, you need to cut a hole in the inner floor section (roughly 22$^1/_2$" wide) for the telescope pier. A hole could be cut in one long section of plywood, but it is easier to piece in two shorter sections of plywood with half-circles cut in one edge. The diameter of the half-circles should be about $^1/_2$" larger than the pipe so the floor won't rub against the pipe and cause the telescope to vibrate. Bridging — pieces that run at right angles to the joists — cut from 2x8s nailed to the joists near the pier will help to fasten the edge of the plywood. Keep these bridging pieces at least $^1/_2$" from the pier.

During the construction of the walls and roof, the floor is exposed to the elements. So I gave the floor and exposed portions of the perimeter joists a coat of exterior primer. Then I filled the pier with sand to help dampen the vibrations when I move or bump the telescope. A scrap piece of $^1/_4$"-thick steel plate seals the top of the pier. Three holes drilled and tapped in the plate help secure the telescope mount. I formed a collar around this plate from 2"-wide strap iron. Set screws in the collar fasten this assembly to the pier. With this plate in place, we are ready to build the walls.

Building the Walls

During the winter, I prefabricated the walls in my garage and transported them later to the work site in my truck. The garage was warm and I could build the walls squarely, something that would have been harder to do at the work site. Only the fold-down sections of the wall were sheathed in the garage because they are short and light.

I built the walls from 2x4s with bottom and top plates and with studs on 16" centers. Three-inch screws or 16d nails fasten the studs to the plates, two fasteners for each



end. I used screws because they won't loosen easily from wind loading on the building.

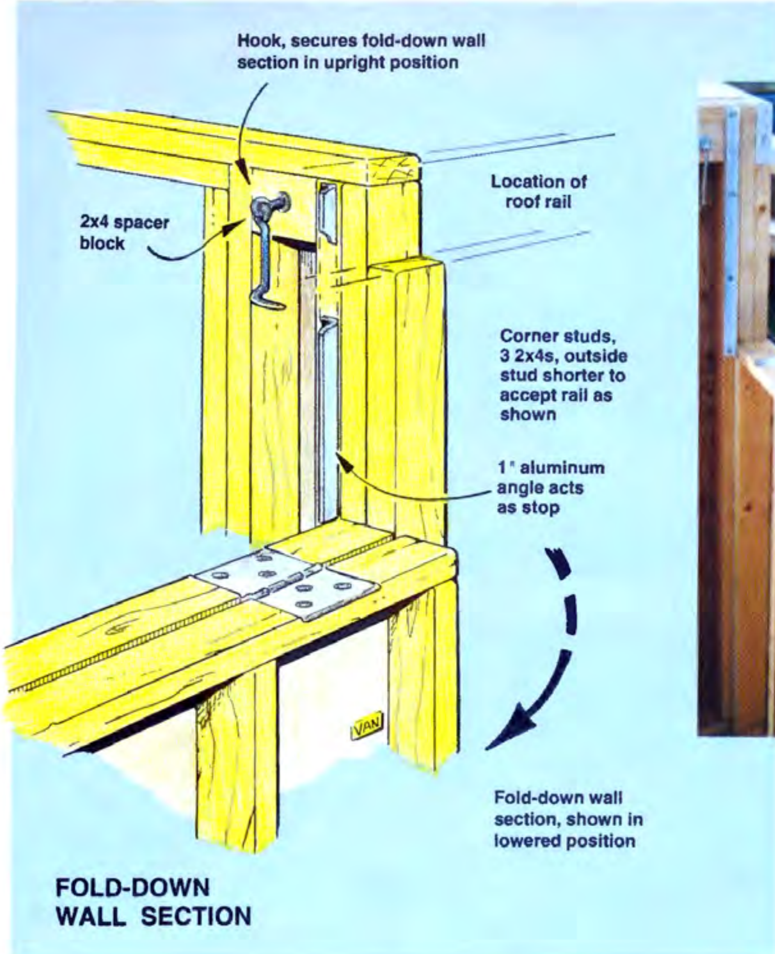
My floor is exactly 10' x 10', so I cut four sections 9'-8 1/2" long for the west and east top and bottom plates, one section 9'-9" for the north top plate and two sections 9'-5" for the south top and bottom plates. The north bottom plate was cut as two pieces to accommodate the door. I chose a 36"-wide prehung door. The wide door makes carrying equipment in and out easy, and since it was prehung, it was easy to install.

The corner studs in both corners of the north wall and the south corners of the west and east wall (see the illustration on page 83) use three 2x4s nailed together. The two extra backing, or jack, studs provide a solid nailing base for the end studs of the connecting walls and help to support the weight of the roof. The north corners of the west and east walls and both corners of the south walls have single studs. Note that one 2x4 in each corner in the north wall is 4" shorter than the others to act as a support for the roll-off roof rails (see the illustration on page 86).

The frame for the door consists of two studs on each side and a 2x4 header above the door screwed directly to the top plate. The header rests on top of the inner stud of the door frame for extra strength. Since this isn't a load-bearing wall, this simple header is sufficient.

The walls are 6' high. (Check your local building codes to be sure you can use such a low wall for an outbuilding.) The north wall studs were roughly 69" long. A standard 80" exterior door — and its jamb — must be cut down 13" to fit this height and still permit a 1" threshold to seal out the weather. Choose a solid-core door so it may be cut easily to length. The bottom door hinge will have to be repositioned since it was in the part of the door that was cut off. Or have a

SHEATHING THE WALLS with overlapping corners keeps water from penetrating the joints (top). If you can't get large sections of OSB for the sheathing, remember to stagger the joints for strength and place factory edge to factory edge for tight joints (above).



FOLD-DOWN WALL SECTIONS swing on four strap hinges routed into the walls (above left and right). Aluminum angles fastened to the jack studs prevent the sections from extending too far when in the raised position. Gate hooks and screw eyes secure the sections when raised. Wood strips guide the router to recess the strap hinges in the wall plates (left). Bolts secure the rails for the roll-off roof to 4x4 posts (below).

millwork company custom build a door and frame for you.

The west, east, and south walls have two sections: the top fold-down section and the rigid bottom section. The fold-down sections use 21" studs, while the bottom sections of the walls use 45" studs.

The studs in the west, east, and south walls are placed on 16" centers from the middle of the wall. Since the 10' wall lengths aren't even multiples of 16", the last studs on each side will lie closer to the corner than 16". This is helpful since reinforced corners will better support the roof load. Three studs in the north wall are placed 16" on center between the corner studs and the double studs for the door frame. (Four studs are shown in the illustration on page 83 because the door opening is shown as 2'.) Small header plates made from 2x4s are screwed or nailed into the corner stud pocket near the top plate (see the illustration on page 86). A gate hook attached to this header secures the fold-down wall section when it is raised.

The fold-down wall sections have top and bottom plates of the same lengths as the rigid wall sections. Unlike the rigid sections, the fold-down sections were sheathed before being moved to the observatory site. I used $^3/_8$" exterior grade oriented-strand board (OSB) for the sheathing.

Look for 4' x 10' sections of OSB or plywood at your lumber store. These large sheets make covering the fold-down sections easy. However, many home improvement stores carry only 8' sections, in which case you will have to piece the sheathing together. Be sure each joint falls over a stud and place the factory edges together for a tight joint. Screw ($1^1/_2$") or nail (6d) the plywood to the plates and studs about every 6".

Erecting the Walls

When the snow cleared from the observatory site and the weather warmed up, I moved the prefabricated walls to the observatory site. The north wall went up first. I aligned the edge of its bottom plate with the outside edge of the floor and screwed the bottom plate through the floor and into the perimeter joists with 3" screws, one screw per stud pocket. I screwed a scrap length of 2x4 loosely to one of the studs. Once the wall was plumb, I screwed the 2x4 to a stake driven into the ground to hold the wall in position during the installation of the other walls. Next, I temporarily placed the other three walls to ensure that everything fit well.

The west and east walls went in next, and screws fastened these walls to the rim joists. Screws driven every 12" also joined these walls to the north wall corner studs. Then I secured the south wall section with screws through the bottom plate into the perimeter joist and through the south wall's end studs into the west and east wall corner studs. The walls were now sturdy enough that the temporary bracing holding the north wall plumb could be removed.

Next I sheathed the rigid wall sections. As with the fold-down sections, I used 3/8" OSB. The sheathing should extend to the bottom edge of the joists. Remember, if you piece the sheathing together, place the factory edges together and stagger the joints for a stronger wall. Be sure that all vertical joints occur over the studs. Screw (1 1/2") or nail (6d) the sheathing every 6" along the edges of the plywood and every 12" along the other stud locations.

When sheathing the walls, it is important to build the corner so it is weatherproof. The sheathing of one wall should be flush with the corner formed by the studs. The sheathing from the adjacent studs should then overlap the sheathing of the first wall (see the illustration on page 85). Extending the sheathing to the bottom of the joist protects the floor-wall plate connection.

Now you can install the door according to the manufacturer's instructions. Once the door operates smoothly and the frame is securely fastened, remove the door until the roof is in place to allow for easier construction. Be sure to allow for the threshold, but do not install it yet. It's a nuisance while construction is underway.

Before installing the fold-down wall sections, you should install the siding. This ensures that the hinge spacing is correct so the top wall section folds down properly. I used 3/8"-hardboard siding. Use long vertical pieces of siding so there are no horizontal joints to trap water, and stagger the joints so they don't fall over the vertical joints in the OSB. Overlap the edges at the corners as you did with the OSB to make the corner weatherproof.

AT THE END OF PHASE 2, the floor, walls, fold-down wall sections, and roll-off roof rails are in place. A good coat of exterior-grade primer will shield the structure from the elements until we can install the roof in part 3 of this series.

Installing the Fold-down Walls

Once the siding was in place, I located the positions for the four strap hinges in each wall section, two hinges about 6" from ends of the wall and the other two spaced evenly in between. I used a router to recess the hinges into the wall plates — two wood strips tacked temporarily into place formed a guide for the router. Once the hinges were fastened securely to the wall plates, the outline of the hinge was traced onto the bottom plate of the fold-down section. (Place a piece of siding between the wall sections so you'll mark the proper hinge location.) After routing these areas, I screwed the fold-down section to the hinges.

As with the rigid wall sections, I installed the west and east sections first so the south section could be test fitted before marking its hinge positions. Two-foot sections of aluminum angle along the north wall corner studs prevent the east and west fold-down sections from extending into the building when raised. Additional pieces of aluminum angle installed along the jack studs of the east and west fold-down sections prevent the south fold-down section from pushing in too far.

I installed headers made from 2x4s into the top corners of each fold-down wall section. Gate hooks and screw eyes screwed in the headers — and those in the north wall — hold the wall sections together when raised. Purchase stout hooks for this purpose because they will be under some strain when the roof rolls on and off the walls.

Roll-Off Roof Rails

The last step of phase two construction is to install the bottom timber of the roll-off roof rails. The shortest member of the corner studs in the north wall supports one end of these rails and posts support the other end. The posts are made from 4x4s and fit into the post brackets north of the building. If the post brackets were installed level with one another, then the height of the posts should be equal to the thickness of the joists, thickness of the floor, and height of the walls. My posts are 6'- 7 7/8" high and have a 1 1/2" deep, 5 1/2" long rabbet cut on the outside portion at top to hold the rail. A 1/2" bolt holds the post to the support. Temporary bracing made from 2x4s kept the posts plumb until the top rails and crossbraces could be installed in phase three of construction.

The rails are made from 13' lengths of 2x6 lumber. The long length permits the roof to be pushed well off the building to give greater access to the northern sky. I screwed one end of the rail to the north wall jack posts and bolted the other end to the post with 4" carriage bolts. To minimize accidents, I beveled the bottom corner of the rail.

The rails signal the end of phase two construction. In the final installment of this series, I'll describe the rest of the roll-off roof rail structure, roof construction, and finishing touches. □

Part one of this series appeared in the April issue of ASTRONOMY and the third and final installment will appear in the June issue.

3 PART SERIES

Building Owl Observatory

In this final installment, you will learn how to build the roof and add the finishing touches to this backyard observatory.

Story and photos by Jim Krick

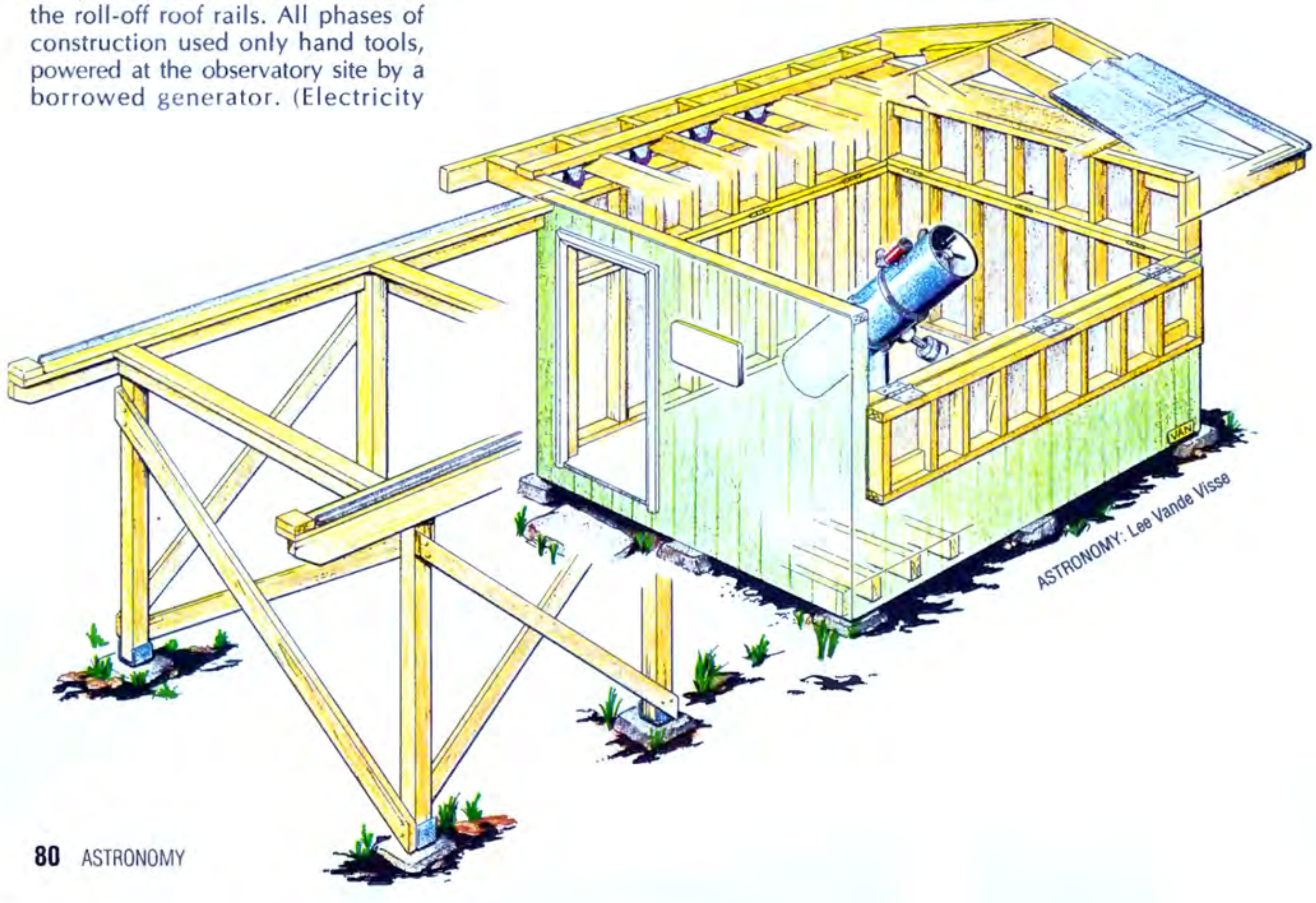
Owl Observatory is a 10'x10' building located about twenty-five miles east of Great Falls, Montana. I built the observatory to pursue astrophotography in comfort during Montana winters. Its elevated wooden floor prevents animals from nesting under the building and is warmer than concrete during the cold winter months. The roof rolls off and the upper two feet of three walls fold down to give me complete access to the sky for astrophotography. Yet the four-foot rigid walls shield me and my telescope from the wind while I'm observing.

Part one of this series described how I built the telescope pier and building foundation and part two described the construction of the floor, walls, and the bottom timber of the roll-off roof rails. All phases of construction used only hand tools, powered at the observatory site by a borrowed generator. (Electricity wasn't provided by the local power company until I had almost finished the observatory.) And the total cost of the observatory was only $1,500. In this last article of the series, I'll tell you how to finish the roll-off roof rails, prefabricate and install the roof, and add some finishing touches. Let's start with completing the siding.

Finishing the Siding

In part two, I described the installation of the $^3/_8$" hardboard siding over the sheathing on the rigid sections of the walls. However, the fold-down wall sections had only oriented strand board (OSB) sheathing applied. First, I installed scrap pieces of OSB sheathing to the corner studs of the east and west fold-down wall sections, overlapping the edge with the previously applied sheathing to form a weatherproof corner. I cut 2'-long, 4'-wide sections of the siding to cover the fold-down wall sections, matching the vertical pattern of the siding on the rigid walls. Then I covered the ends of the east and west fold-down wall sections with siding, again overlapping the edges.

The corners on the north wall also needed scrap pieces of OSB sheathing applied to the corner studs so siding could be installed flush with that of the fold-down wall sections. I used $1^1/_2$" screws to fasten the sheathing



and siding. (You also can use 6d nails.) With the siding in place, the roll-off roof rails can be installed with the proper overhang.

Finishing the Roll-off Roof Rails

The roof rolls toward the north from its closed position on top of the observatory walls to its open position on 2x6 rails elevated by two pairs of posts. These rails have two sections on each side: a 9'-9 1/2" section attached to the top of the east and west fold-down walls and a 13'-1" section that attaches to the 13' bottom rail timbers installed in part two of the construction. I used strong softwood (wood species group II) for these rails so the casters supporting the roof assembly won't wear into the wood. A very hard wood like oak (species group I) isn't necessary, but you should avoid soft woods like pine or cedar (species group IV). Ask at your lumberyard which locally available variety of wood best suits the rail. The growth rings of the wood should be placed down (that is, the crown of the board is on top) to minimize warpage.

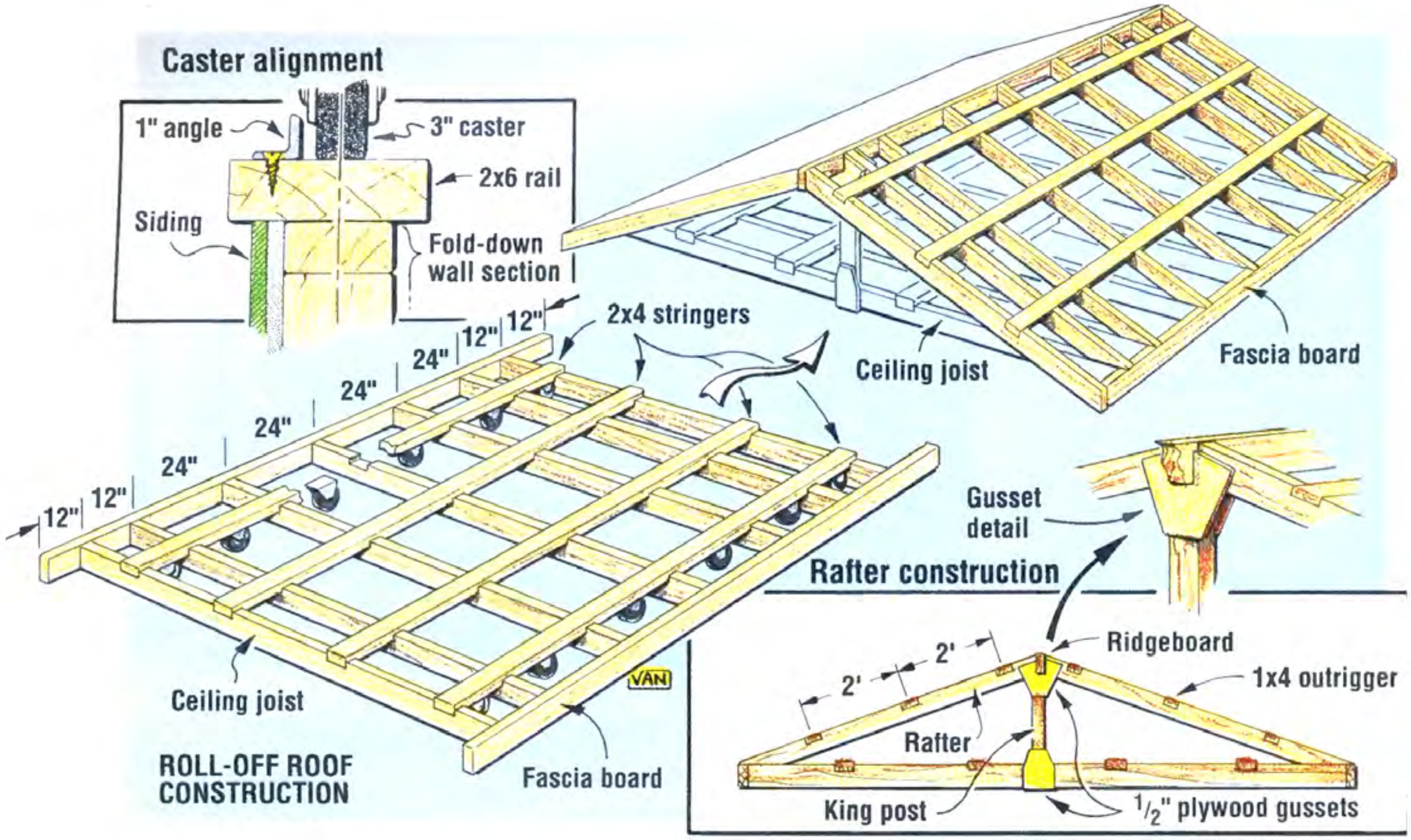
Install the fold-down wall sections of the rail first. I overlapped the 2x6s so about 3/4" hangs over the siding and at the ends. This leaves about 1/2" overhanging the inside of the wall. The slight asymmetry allows for a flush fit with the 3/4"-thick corner caps installed later. Be sure that the 2x6 won't prevent the top section of the wall from folding down. Then attach the rail to the wall with 3" screws placed every 12 to 16 inches.

The remaining rails go on the bottom rail timbers on the north side of the building. Attach the rails so they line up with the rails on the fold-down wall sections. About 1" of the rail should extend over the north end of the bottom timber. Use 3" screws every 12 to 16 inches to fasten the rail but be careful that the screw doesn't split the side of the bottom rail. I trimmed out the rest of the wall sections with 9'-3 1/2" pieces of 2x6 so the tops of the wall will be level. The north and south walls repeat the 3/4" overhang on the east and west walls. The south wall trim required that I remove a 1/2" x 5 1/2" section of the south ends of the rails on the east and west walls to accommodate the 2x6 trim.

Next I installed two more posts to support the rails and built cross bracing for all four posts. First I braced the two posts already in place. Carriage bolts (1/4-20, 5 1/2" long) secure all of the braces. A 9'-9"-long 2x4 acts as a collar tie across the top of the posts on their outside (see photo at top). The cross braces are 12' lengths of 2x4, cut to length after being bolted in place. I put one brace on the inside of the posts and then removed the temporary post bracing installed in part two. A second brace added on the outside of the posts further strengthens the posts. Staggering the braces on the inside and outside prevents having to cut joints for the braces.

The second set of 4x4 posts are 6'-7 7/8" long and have a 1 1/2"-deep, 5 1/2"-long rabbet cut in the top to hold the bottom rail. Bolt the posts in place with a 1/2" bolt through the post bracket in the footing and 4"-long, 1/4x20 bolts to the rails. Then you can install the two sets of side braces. These braces are cut from 8' lengths of 2x4. Two of the braces can be cut to length after being bolted in place, but two need to have the bottom end cut before they are installed. The inside and outside braces should go in the same direction as their counterparts on the first set of posts. This keeps two braces from ending on the same inside portion of a post, resulting in a weak connection. A 2x4 collar tie (9'-9" long) across the top of the second set of posts finishes the bracing.

THE ROOF ROLLS ALONG rails supported by the fold-down wall sections and 4x4 posts (top). Cross bracing made from 2x4s bolted in place keeps the posts plumb. Note that the outer braces go from the top of the left post to the bottom of the right post. The roof was prefabricated in my garage during the winter (above) and later reassembled at the observatory site.



ASTRONOMY: Lee Vande Visse

Building the Roof

As soon as I finished the rails, the roof could go up, because I assembled it in my garage during the winter after I prefabricated the observatory walls. The garage was warm and I could cut the rafters more uniformly than I could at the observatory site. A miter saw makes cutting the ends of the roof rafters easier, but it isn't necessary. All the parts were cut, screw holes predrilled, and the pieces assembled to test their fit. Then I disassembled the roof for transportation to the observatory. I labeled and numbered parts once they were in place to ensure that they would be reassembled in the same positions.

Several considerations went into the roof design. The roof pitch must shed snow in the winter. The roof must also be strong enough to resist strong winds and heavy accumulations of snow. And it must be light enough for one person to roll off and on during an observing session.

The final design of the roof is simple (see the illustration above). The roof is gabled, with the gable ends overhanging the north and south sides of the building by one foot. The eaves on the east and west sides also extend one foot. A rolling frame of 2x4s acts as the ceiling joists and supports for twelve 3"-diameter, heavy-duty, fixed-wheel casters. Fixed-wheel casters keep the wheels pointing along the rails. With six casters on each side, two or three wheels are always in contact with each rail, so pushing the roof along the rails is easy. King-post supported rafters make the 2x4 structure strong enough to resist wind and snow loads. And corrugated steel roofing, instead of plywood decking covered with shingles, makes the roof light enough that one person can push it. I estimate that my finished roof weighs only about 100 pounds.

The seven cross members, or ceiling joists, of the rolling frame are 12' lengths of 2x4. (Orient the $3^{1}/_{2}$" side of the boards vertically.) I spaced the joists 2' apart except at the gable ends, where the spacing is 1'. Four 2x4 stringers that are 10' long hold the joists in place. The stringers fit in $^{3}/_{4}$" dadoes cut in the ceiling joists. The stringers themselves are not jointed. I first screwed the stringers in place with 3" screws and then bolted the joists and stringers together with $4^{1}/_{2}$"-long, $^{1}/_{4}$x20 carriage bolts. The bolts hold the frame together while the screws keep the joints from twisting. Fascia boards, made from 12' lengths of 2x4, cap the ends of the joists.

I selected a 4/12 slope for my roof because of the potential snow load. This slope means that the peak of the roof stands 24" higher than the ceiling joists. Given a 6' rafter run, which is the distance from the edge of the fascia board to the centerline of the roof, the lengths of the rafters must be slightly more than 6'-3".

The rafters need to be supported in two directions. In the horizontal direction, a 2x4 ridgeboard provides a nailing surface for the rafters and keeps them plumb. King posts help support the rafters vertically to prevent the roof from collapsing. The king posts strengthen the roof so much that you can use 2x4s instead of 2x6s for the rafters. (If you don't employ king posts in your trusses, use 2x6s for the rafters; 2x4s are still sufficient for the ceiling joists in this case.) For my 4/12-sloped roof, I used seven king posts that were 1'-$8^{1}/_{2}$" long.

To build the roof on the rolling frame, I temporarily supported the 12'-long ridgeboard with two king posts on the ends. This allowed me to test fit one rafter that I then could use as a template to cut the other rafters. The rafter tail, which is the end by the fascia board, forms an angle of roughly 18.5 degrees while the ridge end has an angle of about 71.5 degrees. (A rafter square will aid in marking your rafter cuts, but you also can mark the cuts while holding the rafter in place.) I avoided a complicated bird's-mouth joint. Instead I used a simple butt joint of the rafter to the ceiling joist.

After cutting all 18 rafters to length, I notched them for three 1x4 outriggers. The outriggers keep the rafters from twisting and provide a surface for attaching the corrugated roofing. I marked and cut one rafter to use as a template to mark the outrigger positions on the other rafters. The first outrigger lies about 1' from the ridge end of the rafter. (Be sure it will clear the gussets described below.) Space the other two outriggers about 2' apart.

When all the rafters were cut, I assembled seven truss assemblies of one king post and two rafters. There are only seven trusses because the end rafters form a gable and do not have king posts supporting them. I also cut out gusset plates from $1/2"$ plywood to strengthen the king-post joints. I used four gussets, two at the bottom, where the king post fastens to the ceiling joist, and two at the top, where the king posts, ridgeboard, and rafters join (see the illustration on the opposite page). I used construction adhesive (not glue) and screws to fasten the gussets to the king posts and rafters (but no adhesive at the joints with the ridgeboard and ceiling joists), because the trusses weren't disassembled for carting to the observatory site.

I built the entire roof in my garage, making sure that all joints fit properly. Every screw holding the ridgeboard, rafters, king posts, and outriggers together was fastened, so construction at the observatory would be simply a matter of reassembly. After it was all assembled, I carefully took it apart for transport to the observatory, checking that each part was labeled to ease the roof's later reassembly. Each part then got a coat of exterior-grade primer. Finally I installed the casters on the outer stringers of the rolling frame.

The ceiling joists create six sections — and thus six caster locations — along the outer stringers. Each section is marked by two holes for the $1/4$x20 bolt that fastens the stringer to the joists. I installed a caster halfway between each pair of bolt holes. A chalk line snapped along the stringer aided in lining up the casters so they all roll in the same direction. With the casters installed, I trucked the roof parts out to the observatory.

Installing the Roof

The rolling frame went back together first. I reassembled on the ground all but the inner stringers of the frame — no sense lifting extra weight — then lifted it onto the south end of the rails. The south wall temporarily supported one end of the frame while I lifted it. With the frame in place, I screwed a block made from scrap 2x6 onto the end of each rail to prevent the roof from rolling off the rail. The north blocks were beveled toward the end of the rail to shed water.

Then I snapped a chalk line just outside the casters to mark the location for pieces of 1" angle (see the illustration on the opposite page). Thick aluminum angle is sturdy enough and is maintenance free compared to steel angle. The angle acts as a guide for the casters when the roof is pushed back and forth. Two 9' lengths of angle suffice for the fold-down wall sections, while the other rails require 13' lengths. I fastened the angles with $1\,1/2"$ screws every 12". With the rolling frame constrained to move along the rails, I installed the roof trusses next.

The roof trusses, ridgeboard, and outriggers were merely re-erected according to the labels on each board and truss. After reassembling the roof, I installed hardboard siding on the gable ends and along the eaves, matching the pattern of the siding on the walls below. Use 6d nails or $1\,1/2"$ screws to fasten the siding. A wooden cove or L-shaped piece of thin, flexible metal fastened along the eaves (where they meet the hardwood rail) helps to seal the gap between the roof and building. I added a 1x4 along the bottom edge of the north gable end. This strip helps seal the gap between the roof and wall when the roof is closed. Before installing the corrugated roofing, I covered the fascia board and gable rafters with a drip edge to prevent rain from working its way back into the building.

You can choose from a wide variety of roofing materials. Steel and aluminum are the most popular and come in many different corrugation designs and factory applied enamel finishes. I chose white to help reflect sunlight during the day.

Installing corrugated roofing is easy. Cut the roofing to length with a powered handsaw equipped with a metal cutting blade (typically this is an abrasive wheel). And be sure that you use the proper fasteners for the material you are using. The

THE ROLLING FRAME was reassembled at the observatory on the ground and lifted into position (below). One-inch aluminum angle, screwed every 12 inches along the length of the rails, guides the frame's casters when rolling the roof back and forth (left).

RAISING THE ROOF starts with preassembled king-post trusses that are screwed to the joists in the rolling frame and ends with corrugated metal roofing that attaches to three 1x4 stringers (photos from top to bottom).

wrong screws or nails will produce a chemical reaction, weakening the roofing and thereby leading to roof leaks, and panels being torn off by the wind. The screws I used have a neoprene washer near the head, which automatically weatherseals the screw hole.

Although you should follow your roofing manufacturer's instructions, I'll describe how my roofing panels went in. As I placed each piece of roofing, a piece of weatherstripping went between the fascia board and the roofing. Weatherstripping also went between the roofing and the gable end rafters. Some manufacturers also give you an adhesive piece to place between the overlapping sections of roofing. This strip helps seal the gap between the two pieces of roofing.

I placed all the pieces flush with the ridge ends of the rafters and with a 1" overhang at the fascia board. The first piece overhangs the gable rafter edge by about 1" and has a corrugation for strength. I filed the end that hangs over the fascia board to remove any sharp edges or burrs. The next piece overlaps the previous piece at a raised corrugation so rain will travel down the corrugation and not into the building.

Each corrugation got a fastener at each outrigger and at the fascia board. Winds at my observatory often exceed 25 miles per hour, so I wanted each panel fastened securely to the roof supports. The panels I used were 34" wide, so each sheet covered about 30", accounting for the overlap of the corrugations. Your roofing may cover more or less depending on its width and the corrugation pattern. About 4" had to be cut off the length of the last panel to leave a 1" overhang on the gable end. (Make this cut next to a corrugation, if possible.)

Capping the roof took place once all the roof panels were installed. I bought a one-piece roof cap painted the same color as my roofing. It too is preformed for strength. I fastened the cap to the ridgeboard with screws and neoprene washers about every 16". A space may exist under the cap at the gable ends, but mice and birds can't enter the building this way because the roofing extends up to the ridgeboard.

Before starting the finishing details of the observatory, I provided a means of securing the roof. I didn't want someone forcing the roof open and gaining access to the observatory or a strong wind blowing the roof off the building. I tried gate hooks but they didn't work very well. Now I use chain tensioners — called boomers by some people — which are available from many hardware stores. Four large eye bolts in the ceiling joists line up with large screw eyes in the studs in the fold-down wall sections. Hooks in the ends of the tensioners fit in the screw eyes and eye bolts. A turnbuckle and a hinge-and-lever mechanism allow the tensioner to be closed with just the right amount of tension to secure the roof.

Finishing Details

With the roof in place, it's time to add the finishing touches. These details include finishing the floor, adding corner caps, and painting the building. I didn't clad the inside of the walls. That's a project I may undertake after I enjoy using the observatory for a while. But you may wish to install the interior wall cladding at this time, using gypsum wallboard (sheetrock), paneling, or wood siding.

Unless you put in a 1"-thick plywood floor at the start, the floor is really a subfloor and you should install a second layer, or underlayment, of plywood or particle board. The actual type of underlayment depends upon the flooring you decide on. If you wish to paint the floor, a good grade (AC) of $1/2$"-thick exterior plywood will do. Use an underlayment-graded plywood, if you can find it, because voids between its plies have been filled, preventing shoe heels from punching holes in the floor. Fill all joints with an exteriorrated floor-leveling material prior to painting. Otherwise, the joints will harbor dirt and dust that will eventually find their way to your optics. Outdoor carpeting or tile requires a dense particle board underlayment that is $1/2$" to $5/8$" thick. Whether you install plywood or particle board, place a bead of construction adhesive between the subfloor and underlayment and screw ($2\,1/2$" long) or nail (10d) the underlayment to the floor joists.

After finishing the floor underlayment, I installed the door threshold and rehung the door. Weatherstripping around the door prevents dust, rain, and snow from blowing into the building. My door didn't have holes predrilled for the door knob and lock, which was fortunate because I had to cut the bottom off the door. The knob would have ended up too low for normal use. I installed the door knob about 36" above the floor.

Trim around the door opening covered any gaps between the door

THE FINISHED OWL OBSERVATORY has siding installed in the gable roof ends and along the roof eaves, corner boards made from 2x4s, the door replaced, door trim, and a coat of exterior paint.

frame and siding. I used standard brick molding, but you also could use other milled woodwork for the door trim. Avoid casings with a grooved back, because the hollow could trap water that will eventually rot the woodwork. I used 10d finish nails to attach the trim to the studs in the door frame.

To further prevent rain from penetrating the corners and damaging the siding, I built caps for the four corners of the building. If your strap hinges do not give you sufficient clearance (mine swing the fold-down wall sections $1^1/2$" away from the rigid walls), you may wish to forego corner caps or use a thin aluminum cap. The caps could be built from 2x4s, but I used 1x3s and 1x4s. Using a 1x3 on one side of the corner and a 1x4 on the other gives a nice square appearance. The tops of the caps fit flush against the roll-off roof rails. The north wall corners are easy to build because the caps extend the entire height of the wall. The south wall caps are more difficult to make because the east and west walls fold down, requiring a joint in the south corners.

I made the caps for the south corners in two pieces. The joints on the south side of the corner have a mitered joint, with the angle pointing down. The top of the first piece fits flush with the top plate of the rigid wall, while the inside edge of the second piece fits flush with the bottom plate of the fold-down wall. A butt joint would work for the south side, but mitering the joint helps to shed water. The east and west sides of the corner use simple butt joints since a mitered joint would interfere with the motion of the fold-down wall section.

With the roof installed, the door rehung, the floor laid, and a few details like corner caps finished, it was time to paint the observatory. I chose light colors to enable me to see the immovable objects like posts that I don't wish to run into at night. A card table and a chair provide the basic furniture needed for my observing runs.

To commemorate the completion of construction, my wife Colleen gave me a redwood plaque engraved with the latitude and longitude of the observatory and with the year of construction to hang on the building. But I doubt that my observatory is finished. The building's design started as an answer to a list of inconveniences I suffered while observing. As my observing needs change, I will probably alter some things and add others.

After six years of planning and dreaming about having an observatory, I'm glad that I built it. No more batteries and inverters to carry so I have power for my telescope's drive. The walls protect me from moderate winds while I am trying to photograph the skies. And my feet are warmer than they were standing on the ground during the winter. Owl Observatory has fulfilled my dreams. □

Jim Krick uses his observatory to introduce children to the wonders of the night sky. Parts one and two of his series appear in the April and May issues.