Box Beam Module Framework

General Introduction

This design is part of an effort to come up with framework that was both light weight and strong. Good resistance to sag and twist are combined with a reasonable light weight and ease of construction. Lighter weight than this requires thinner plywood and quite a bit more detail work to reinforce key points during construction. Any light weight NTRAK module should be able to be used with existing modules. It should be strong enough to withstand not only the usual transportation handling it should also be able to be clamped up in a string of modules that have to be "horsed around" to close the gap to complete a big layout. We often have all available bodies lifting and shifting a string of modules to bring them into alignment. This is most likely the greatest stress a module frame must withstand.

The rear of the module can be stiffened by taking advantage of the skyboard. Using two bolts to fasten the skyboard to the back of the module makes the skyboard decorative. Adding a third bolt in the center makes the skyboard structural as well.

A table saw is just about a necessity when building this module. Using a hand held circular saw will mean careful use of saw guides to get several pieces the exact same width. You will also need either a hand held drill or a drill press. I used a drill press as well as a radial arm saw, jointer, disk and belt sanders in building the prototype framework.

The legs, braces, corner blocks and glue strips were ripped from 2"x10" white fir used for Fascias at the edge of the roof on homes. Readily available here in California, the boards are smooth on one side and rough sawn on the other. A variety of short lengths are needed for the project, so I was able to work around the knots in the material. Spruce, cedar, Pondorosa pine or cypress would also be good. I would avoid yellow pine or Douglas fir. Both are heavier and tend to split. The legs are 1-1/4" square and the leg braces are 1-1/4" x 1/2". You could save a bit of weight by making the legs 1" square and the braces 1" x 3/8", but that is as small as I would go. It would save about 3# on the 7-1/2# leg assembly.

The key to constructing framework with thinner plywoods is close fitting glue joints and a high strength glue. I used "Tite Bond II" glue which has high strength and is water resistant. There is no danger of failure while water based scenery work is being done. Yellow "carpenter's glue" is better than white glue, but not as strong as "Tite Bond II".

If you start out with a full sheet of plywood, a power hand saw and guide will let you cut it into smaller pieces that are easier to handle. If you have to make the cuts on a table saw, make the pieces oversize so that you can accurately re-cut them to size later. If a cut wanders, straighten up that edge before cutting more pieces. You need one true edge to work from when cutting pieces to exact size.

Plywood comes in many grades. When I started this project I bought a sheet of 1/2" plywood and cut some parts from it. The next day a long narrow piece looked more like a snow ski that a straight board. A close look showed that the 1/2" ply had only four plys rather than the five plys that I had seen in 1/2" plywood over the years. I went back to the lumber yard and found that all of their 1/2" was four ply. I checked at four other places and only one had any five ply 1/2". I called the Douglas Fir Plywood Association and they said that the 4 ply had been in use for several years and is primarily to be used as full sheets in home construction. There is even a 3 ply 1/2" that is also used in home construction. If you can find it, I'd use five ply grade A-C X (good top, open knots on bottom and exterior glue). Some grades classify the top as "plugged and sanded" which is often 1/32" undersize and you will need to adjust your dimensions to account for the thinner material.

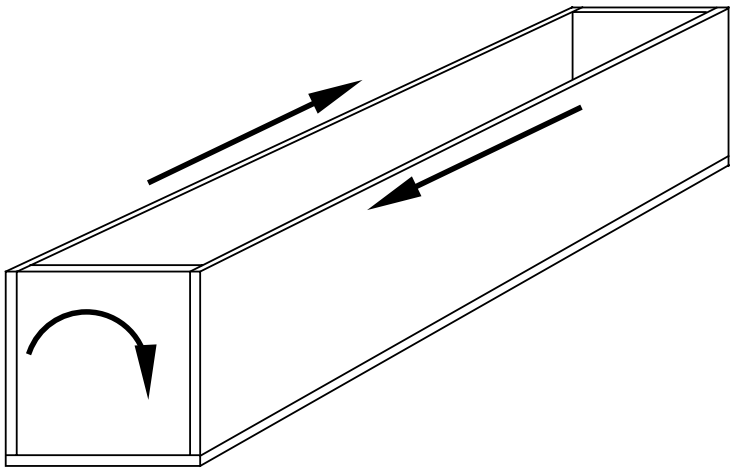
A superior plywood is used for cabinets and is called "Baltic Birch" or "Finnish Birch". The 1/4" thickness has 5 plys, 3/8" has 7 plys and 1/2" has 9 plys. Baltic Birch isn't cheap, about twice the cost of regular plywood. Local lumber outlets may not stock it, but can order it from a speciality supplier. You could also check with cabinet shops. I have used it for several projects over the years and seldom find any voids in the inner plys. It comes in 5' square sheets, so there is waste if you are building 4' long modules. I am building a pair of 5' long modules that will always be used together. I have the shorter Plymouth mini van and while it will hold 6' modules near the floor, as you get higher up the slope of the back and slope of the seat combine to reduce the length that can be carried. I plan a rack that will hold the 5' modules above two 6' modules. The 5' modules will also fit in Chevy Blazers and small wagons.

For this design I have used 1/4" ply for the top and bottom, 1/2" for the frame and 1/4" for the skyboard. You could use 3/8" for all parts. For the frame you would need to double the thickness in the areas where modules are "C" clamped together and where the skyboard bolts to the frame. This adds a few more pieces, but reduces the weight some and eliminates one thickness of plywood to buy. Edge glued joints with 3/8" ply are very strong with "Tite Bond II" glue if both surfaces are fully coated before clamping.

There are alternate designs in this series for wider modules with a sloping front, for openings under the tracks for a stream or highway underpass and for folding legs. They will be covered in book expected to be published by NTRAK in late 1994.

The Box Beam

An open three sided box distorts easily when twisted. Adding a fourth side to the box creates a very rigid box beam. With glue strips along the seams, even 1/8" thick plywood will make a very rigid beam. You get close to the stiffness of a timber that size, but without the weight.



Framework Construction

Study the drawing and parts list to get a good idea in mind of the project and the options in material size and whether you want to include the storage compartment in the center box beam.

The front and rear frames are 4" high and the module top is flush with the top of the frames. This hides the edge of the plywood from the front. Scenery covers the edge of the frame. The ends are narrower and the module top goes over the ends. Glue strips are used to reinforce the joints between the frame and the top.

Before you start cutting the parts, check the thickness of your plywood. I have found so called 1/2" plywood that was 15/32" thick. You will need to adjust some widths if your ply is thinner. The dimensions on the list are all based on 1/2".

If you are building just one 4' module you will need a 2' x 4' piece of 1/2" ply, a 4' x 4' piece of 1/4" ply and a 2" x 10" x 8' white fir board for the legs and braces. A 6' long board with very few knots might do it, but you will have more flexibility with an 8' long board.

From the 1/2" ply rip two 4" wide strips for the front and back. Then rip a 3-3/4" wide piece for the ends and three 3-1/2" pieces for the sides of the box beam and the box spacers.

From the 1/4" ply cut the top 23" wide. Try to have one corner of this piece an original corner from the plywood sheet, so that you have a good square corner to work to. Mark this corner top and bottom for reference at assembly. Cut the bottom 5-1/2" wide (or 6-1/4" wide if you add the storage compartment door). There is enough material to make the skyboard from the 1/4" ply. See the discussion on skyboards for alternate designs.

I prefer to rip the legs and braces from a wide board and work around the knots. In general I try to find clear wood for the legs first. You are looking for 36" between the knots and 1-1/4" width. You might find them near the edge, but if there are some clear areas toward the center, make a first cut and then cut to width from that cut. Once you have the material for the four legs, then shift to the 1/2" wide braces. I cut about 1/32" oversize and then use a belt sander to smooth the pieces. A jointer tends to chip out near knots, so I seem to get better results with a belt sander. Because you will need many different lengths to do the leg braces, just cut most of the remaining material into 1/2" width. You do need some scrap from the leg pieces for corner glue blocks and you need some 3/4" width for the four leg stops. You will need about 12' of1/2" sq pieces for glue strips. These can be cut from some of the brace scrap. The legs and braces can now be cut to 1-1/4" width by removing the rough sawn edge. If your material was smooth on all four sides, you have the flexibility of trimming the side with partial knots.

Now is the time to cut pieces to length. A radial arm saw is easier for this job, but it can be done with a table saw. When several pieces the same length need to be cut, I either stack them to get the same length or I clamp a scrap of wood to the front part of the rip fence. Use that to set the length of the piece to be cut and use the miter gage to hold the piece square. As you push it toward the blade, the piece is no longer touching the stop and has room to turn after it is cut off without jamming between the blade and the rip fence.

On my finished frame I like to get rid of the sharp edges so there are no splinters or scrapes from handling the module. Much of this can be done after assembly, but some is easier now. The bottom edges of the four frame pieces and the corners of the legs could be run at 45˚ on a jointer at this time. The leg stops can have one corner rounded and edges on two sides broken. You can also make the pins from the double headed nails and drill holes for these pins in the stops now. I rounded off the web under the head of the double headed nails and cut to length so that about 1"

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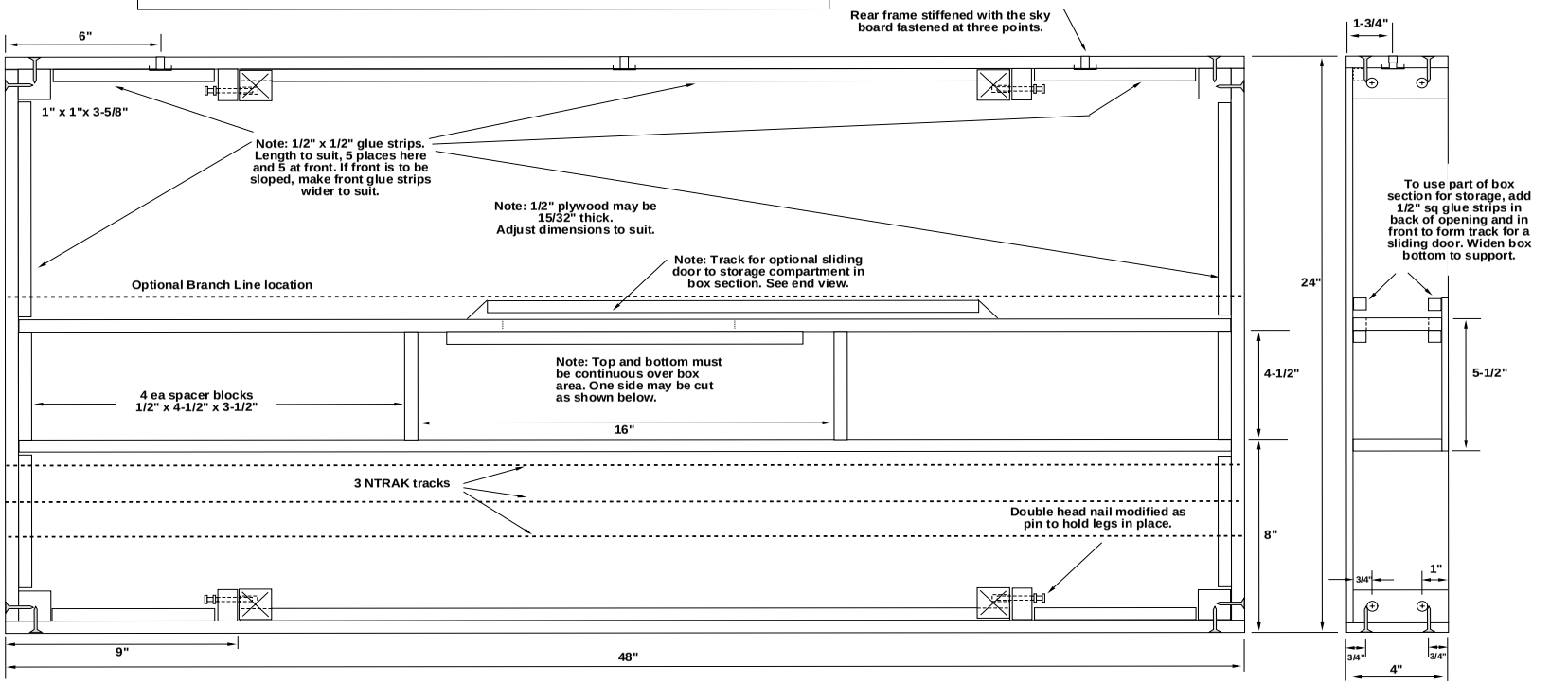
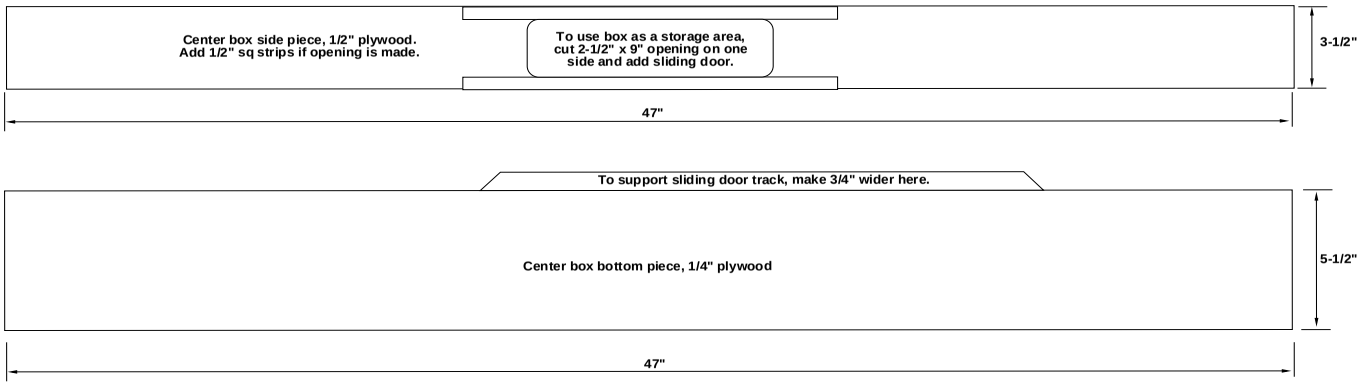
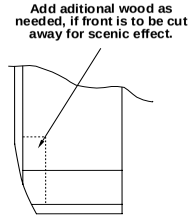
Box Beam Module Frame

4' x 2' x 4" high module, 1/4" top & 1/2" frame, center box beam.







sticks through the stop. Round the end of the pins. The pins should go easily into the holes by hand.

If you are going to have the storage compartment, you need to cut the opening and trim the bottom piece to shape.

For maximum strength, I use wall board screws to hold the corner glue blocks in place. Drill and countersink the end pieces and the front and back pieces so that the screws go into the middle of the block and miss each other top and bottom. See drawing.

As a check at this point I do a "dry" assembly of the parts to try and be sure that all the lengths are right and I have all the needed parts. It is easier to make changes now than when you have glue on everything.

Now it is time to start some sub assemblies. Start with the glue blocks on the end pieces. After coating both surfaces with glue, I "C" clamp the parts together, check that the block is flush with the ends and the top before putting in the screws. Careful adjustments here will mean an accurate finished frame. Wipe off excess glue as you work. Next add a box spacer positioned flush with the top. Now add the glue strips flush with the top. Leave enough room for the box sides between the spacer and the strips.

The leg stops can now be fastened to the front and back pieces. The top of the stop is 1/4" down from the top of the frame. I use a scrap of 1/4" ply to get this right. The stops can be held in place with small nails while the glue is setting up. Now add the glue strips 1/4" down from the top. Keep the area where the corner glue blocks will be in the clear.

Now to the box beam. If you have opened up for a compartment door, add reinforcing glue strips above and below the opening. Add the box spacers in the center being sure that the ends of the box sides are even. Now let the glue set on all of these assemblies.

Parts list for 4' x 2' module with center box beam, 1/2" &1/4" Douglas Fir plywood

Top	48" x 23" x 1/4"	1 pc
Box bottom	47" x 5-1/2" (or 6-1/4") x 1/4", see drwng	1 pc
Front & Back	48" x 4" x 1/2"	2 pcs
Ends	23" x 3-3/4" x 1/2"	2 pcs
Box, sides	47" x 3-1/2" x 1/2"	2 pcs
Box spacers	4-1/2" x 3-1/2" x 1/2"	4 pcs
Corner glue blk	1-1/4" sq x 3-3/4" (wht fir)	4 pc
Leg stop	3-3/4" x 1-1/4" x 3/4" (wht fir)	4 pcs
glue strips	1/2" x 1/2" (wht fir)	12' min
"T" nut retainer	2" sq x 1/4"	3 pcs
Optional sliding door	11" x 3-7/16" x 1/4"	1 pc
Sky board	47-7/8" x 16" x 1/4", see text	1 pc
Legs	1-1/4" sq x 36"	4 pcs
Braces 1-1/4" x 1/2"	40"	1 pc
	35"	2 pcs
	32"	1 pc
	28"	1 pc
	20"	1 pc
	17"	4 pcs
	10"	4 pcs
	1-1/2"	4 pcs
Brace plate	5" x 5" x 1/4"	2 pcs
1/4"-20 "T" nuts		15 ea
1/4" x 3" eye bolts (leg leveling)		4 ea
1/4" wing nuts (leveling bolt locks)		4 ea
1/4" x 2" eye bolts (skyboard)		3 ea
1/4" x 2" hex head bolts (braces)		8 ea
1/4" x 1-3/4" hex head bolts (brace centers)		2 ea
1/4" elastic stop nut (brace centers)		2 ea
1/4" flat washers (brace ends, brace ctr & skyboard)		17 ea
Double headed construction nails (leg retainlng pins)		4 ea
#6 x 1" wall board screws		16 ea

Need 1 pc 1/2" ply 2'x4', 1 pc 1/4" 4'x4', 1 pc 2 x 10 x 8' white fir

For the final assembly you need a flat working surface. One area of the floor in my workshop is quite level and I use that area. A heavy table or 3/4" ply on saw horses would also work.

First complete the frame in the same manner as putting the glue blocks in place. Coat with glue, clamp, check alignment and screw together. With the frame on a flat surface, make sure the top will fit in place, apply glue to all mating surfaces and use small nails to hold in place. Check that the end frame matches the square corner that you marked earlier.

With the frame upside down check that the box beam will slide in place. If all is OK, mark where the beam touches the top so that glue can coat those surfaces. The easiest thing now is to clamp the ends of the box to the spacers with a “C” clamp and add weights to the box to hold it against the top while the glue sets.

When the glue has set you can glue on the bottom to the box beam. If you have the compartment, be sure to mount the 1/2" strips that will act as the guides for the sliding door made from 1/4" ply. Leave clearance so that it will slide easily after it is painted.

After sanding all joints and corners, seal or paint all surfaces so that the moisture level stays the same throughout the framework. This will reduce the chances of warping and problems while working with water based scenery materials.

Legs

Rather than bolt the legs directly to the frame, the legs are crossed braced and form a rigid separate assembly. The module frame simply rests on the legs and pins made from double headed nails hold the two units together so that the legs won’t drop off when the module is moved. If a leg happens to catch in a crack in the floor as the module is being shoved, the legs do not put any twisting or bending movement into the module frame. The legs are 9" in from the ends of the module to reduce any chance of sag in the module. The cross braces are permanent on the pairs of legs for either end and 8 bolts hold the braces in place. Each pair of braces has a center bolt with an elastic stop nut. The rear braces are shorter and mounted up high to give easier access to the area under the module for storing tools and train boxes.

An alternate plan would be to have the braces without the offset and use an 1-1/2" long scrap block of leg material in the center. The block would glue to one brace and a heavy screw would let the other brace pivot. Then one brace bolts on the inside and the other on the outside. This would be easier to build, but a bit harder to assemble and disassemble. There can be a clearance problem with the permanent braces on the end pair of legs.

A “no tools” option would be to use Velcro and dowels instead of bolts. Hardwood dowels 3/8" or 1/2" diameter would be used. Matching holes would be drilled in the braces and legs and then the dowels rounded on one end and glued into the braces. The rounded end of the dowels should be a sliding fit in the legs holes. You might have to sand some to get a good fit. A ring or patch of Velcro is then glued and stapled to the mating surfaces. Be consistent so that the hooks are always on the legs and the fuzzy part on the braces.

To make it easier to drop the module frame on the legs, the leg assembly is 1/16" to 1/8" smaller than the opening on the bottom of the frame. I also sanded a taper at the top of the outer sides of the legs to ease them into the opening. A 1-1/2" long piece of the brace material is glued 2" down from the top on the legs to support the frame.

The plus or minus 1" adjustment for the bottom of the legs is with a 1/4" eye bolt and “T” nut. A full thread bolt or carriage bolt could also be used, but an eye bolt is easy to adjust without tools. I add a wing nut to the assembly to keep the eye bolt adjusted and tight. Without it the bolts wobble some.

You need to drill a hole in the center of the bottom of each leg. Check the outside size of the brand of “T” nut that you buy. The ones that I use need a 19/64" drill. A 5/16" drill will work, but the “T” nut is apt to get loose and give trouble later. If you have a floor model drill press, you can stack blocks and put the leg on the blocks and swing the table to one side to brace the leg as you drill it. A hand drill can also be used if you carefully line up the drill. A helper for this will make it easier. A Shop Smith set up as a horizontal drill press really makes it an easy job. One other method is shown on page 66 of the NTRAK ‘How-to’ Book. It uses a jig that you clamp to the leg to guide a hand held drill. In any case you need to drill the hole deep enough for the bolt to go all of the way in.

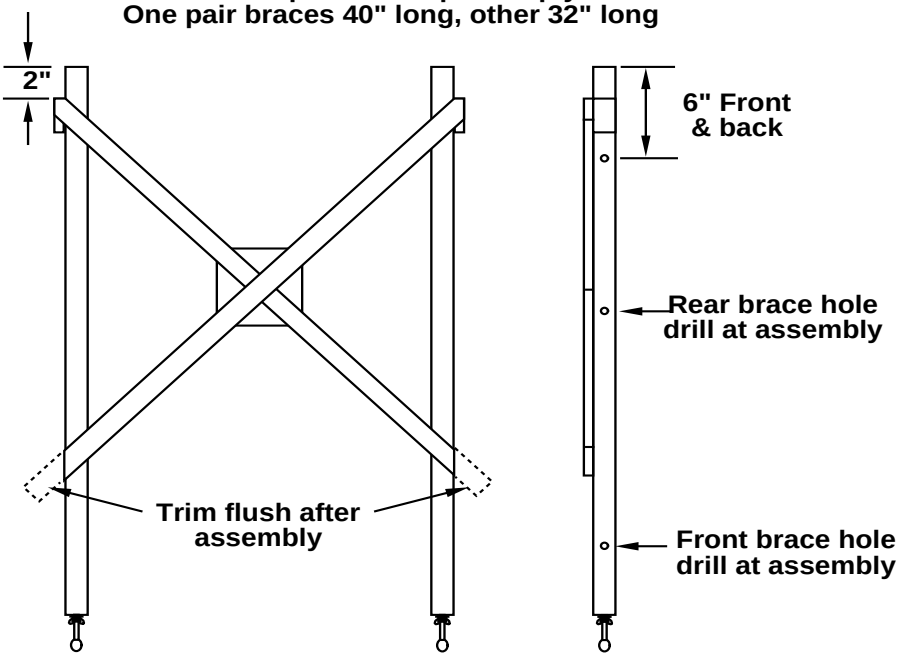
The end cross braces are made by gluing the 5" square brace plate in the center of a 35" long brace. Have the tips of the square plate on the center of the brace. Use small nails and glue to hold in place. Now fasten 17" pieces at right angles to the long brace to make a cross. A carpenters square will check that the brace angle is square. When the glue is set, you are ready to fasten them to the legs.

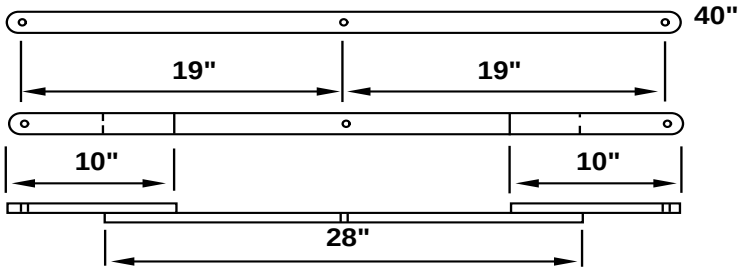
It is important that the legs are parallel, the right distance apart and the bottoms even. I clamp one leg at the edge of a piece of plywood and even with a square bottom. I then clamp the other leg the right distance away and with the leg bottom also at the bottom of the plywood. Now place the assembled cross braces so that the inner edge of the brace is 2" down from the top of the legs. Adjust until the brace is centered, mark and then glue and nail in place. The small nails are just to hold until the glue sets.

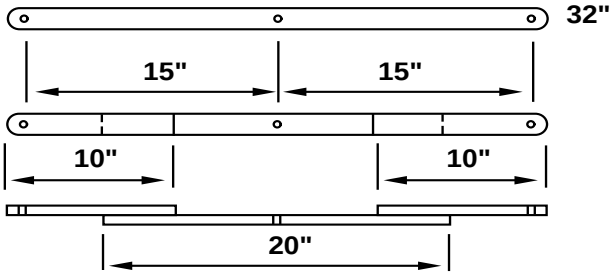
Add the 1-1/2" long pieces of brace that act as stops 2" down from the top. After the glue is set trim the ends of the

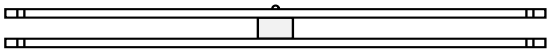
braces flush with the stops at the top and the legs at the bottom. Sand and round the edges. Drill holes 6" down from the top either to fit the "T" nut you are using or to fit the dowel size. These holes are for the top of the pairs of cross braces. Now make a trial assembly of the whole leg system and use clamps to hold the drilled holes in the lower ends of the braces on the center line of the legs. I do all of this in the upside down module frame. This lets me get the right clearance for the legs to go in and out easily. The smaller brace goes at the rear of the module. The assembly should be positioned so that the stops are resting on the frame and everything is square. When all is set, spot drill the legs through the holes in the ends of the braces. Take apart and complete drill the holes, install the "T" nuts or dowels and your leg assembly is complete.

Cross Braced Leg Assembly
Legs 1-1/4" sq x 36" Braces 1-1/4" x 1/2"
Brace plates 5" sq x 3/8" ply
One pair braces 40" long, other 32" long









Alternate brace design.
Glue 1-1/4" sq block to center of one brace and use heavy wood screw for pivot of other brace.

Skyboard

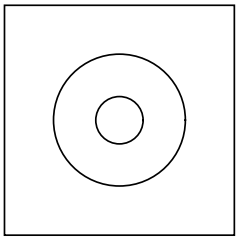
The skyboard can be 16" high. If you are building several modules, you can get three of them from 4' wide plywood. The length of the skyboard should be about 1/8" less than the length of the module. This will eliminate any interference with the adjoining modules. If the same plywood is being used for the module frame and you are building 4' long modules, cut the 4'x8' sheet into one piece that is exactly 48" long and use that for the frame parts and the slightly shorter piece for the skyboard.

Half inch plywood is heavier than needed. Three eights inch thick works out fine and is quite simple. To use 1/4" ply or thinner requires a frame of some sort to stiffen the plywood and to make a top surface that you can lean on with some comfort. By the time you add the frame you have saved very little in weight over the 3/8" ply and have a more complex piece to build.

By using three mounting holes the skyboard becomes a structural part of the module frame. It keeps the frame from sagging.

The 16" tall skyboard is mounted 1" up from the bottom with holes 1-1/4" from the bottom of the skyboard. If you are doing just one module, you can lay out the hole pattern, clamp the skyboard to the frame and drill the holes. If you plan to build several modules, then a jig will make all the hole patterns the same and any skyboard will fit any frame.

Eye bolts can be used to hold the skyboard onto the frame. These are a "no tool" method of holding the skyboard in place. I like to add a small square of plywood behind the "T" nuts so that they don't get pushed out as you try to start the bolts.



2" square "T" nut retainer made from !/4" or 3/8" ply. Cut through 1 ply with a spade bit larger than the "T" nut. Then drill through with same size drill as used to mount the "T" nut. Use small nails to hold in place.