17. Helicopter

This is a challenging but rewarding toy to build. The main rotor (the blades on top of the helicopter) rotates as the body of the helicopter is pulled or pushed across the floor.

This toy can be propelled by hand (the version below), or a pull string can be attached to the nose. The finished helicopter is shown in Figure 17-1. An x-ray view below the photo shows the rotor drive mechanism – one of the more difficult parts of this toy to construct.

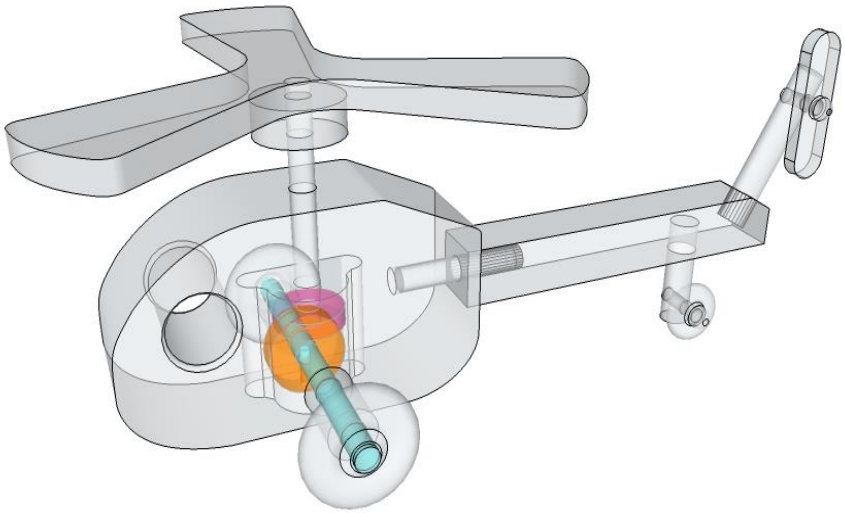

Figure 17-1.
Helicopter

Materials and Tools

This section includes the wood cut list, other parts, and tools needed to construct the helicopter, followed by a parts explosion (Figure 17-2).

Wood Cut List[32]

Part	Material	Size (thickness, width, length)	Qty
Body	Hardwood	1 ¾" x 3 ½" x 6"	1
Tail boom	Hardwood	⅞" x ⅞" x 6"	1
Tail rotor	Hardwood or BB[33]	¼" x ⅝" x 2 ½"	1
Main rotor	BB or Hardwood	⅜" x 9" x 9"	1
Main rotor hub	Wood slab wheel	½" x 1 ½" diameter (TWF150)[34]	1
Vertical drive wheel	Treaded wheel	½" x 1 ¼" diameter (TWT125)	1
Horizontal drive wheel	Wood slab wheel	⅜" x 1" diameter (TWF100)	1
Vertical rotor shaft	Dowel	⅜" x 3 ¼"	1
Glue dowel	Dowel	⅜" x 2"	1
Wheel axle	Dowel	⅜" x 5 ¼" (cut-to-fit)	1
Wheel spacers	Dowel	¾"x 1 ⅛"	2
Drive wheel locking pin	Dowel	3/16" x 1 ⅛"	1
Tail wheel strut	Dowel	½" x 1 ¾"	1
Tail rotor support arm	Dowel	½" x 2 ¾"	1

Other Parts

Part	Material	Size	Qty
Wheels	Hardwood	9/16"x 1 ¾" diameter (TW1750)	2
Tail wheel	Hardwood	⅜" x 1" diameter (TW1000)	1
Tail wheel axle	Axle peg	7/32"	1
Tail rotor axle	Axle peg	7/32"	1
Washers	Steel or plastic	¼"	2
Screw eye (optional)	Steel		1
String (optional)	Nylon	22"	1

[32] Part numbers listed in parenthesis after the description of certain parts are from Woodworks, Ltd. Other suppliers will have similar parts.
[33] BB = Baltic birch
[34] This wood slab wheel can be made rather than purchased. See Chapter 18 on the making of wheels.

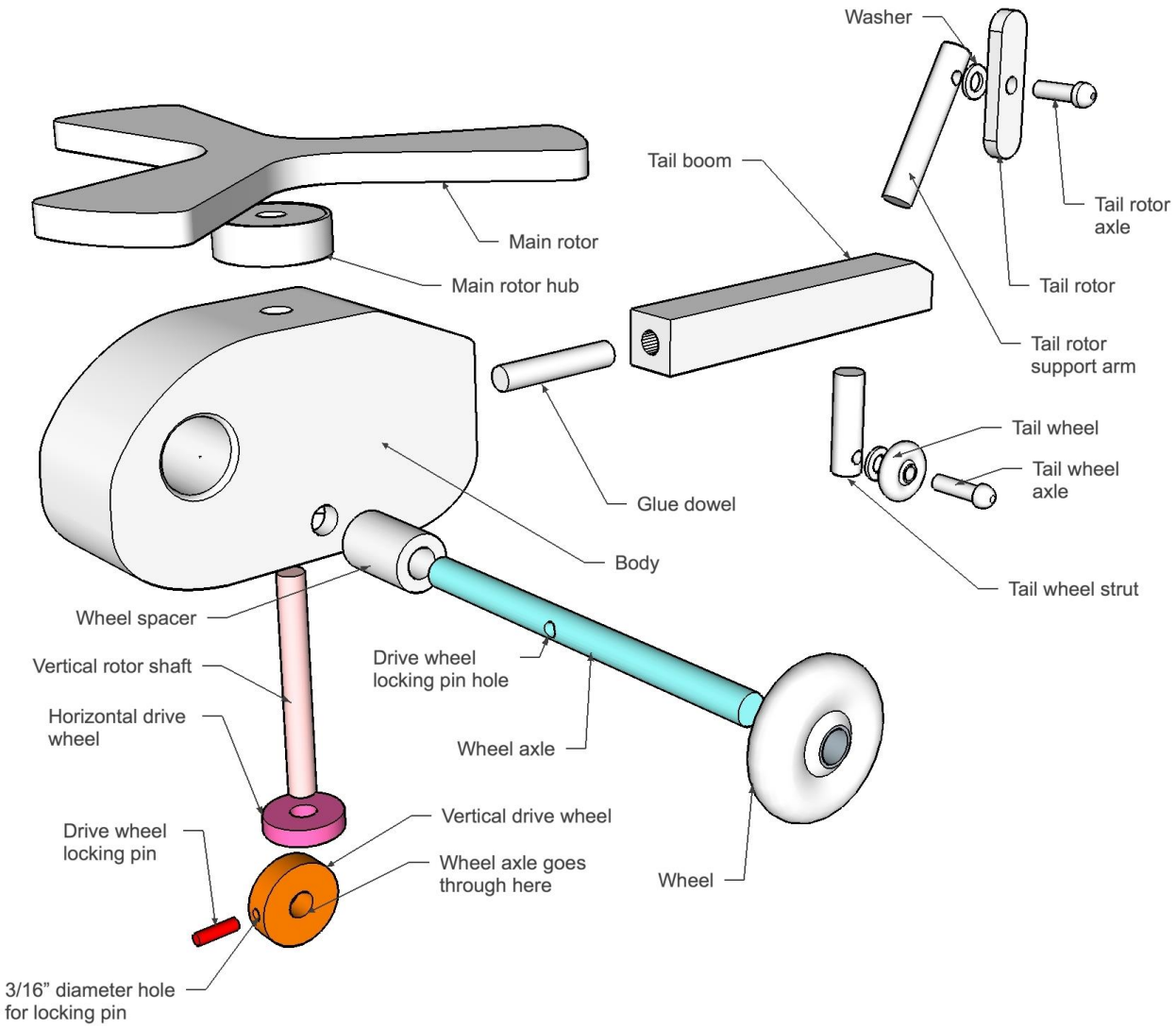

Figure 17-2. Helicopter Parts Explosion

Tools Required

- Woodworking tools and supplies (see Chapter 2, pp. 14-15)
- Special tools for this toy:
  - Twist drill bits: $^{13}/_{32}$", 3/8", $^{15}/_{64}$", 1/4"
  - 1" spade or brad point bit
  - 1 1/4" Forstner bit
  - 3/8" Forstner bit
  - 1/2" brad point bit
  - Chisel
  - Pliers

Drill Bits

See Chapter 19 (pp. 166-7) on the types of drill bits used in toy building.

Plans and Steps

Body

1 – Prepare blank. Cut out a piece of hardwood 1 ¾" thick, 3 ½" wide and 6" long, larger than needed to allow for shaping the body.

Side, back and bottom views of the body are shown in Figure 17-3. This drawing is not actual size. A template for the body that is to scale is given in Figure 17-4. Using this template, mark the outline of the body on the rectangular blank and locate all the holes to be drilled into the side, back, and bottom of the body, as shown in Figure 17-3. Indent the center of the holes with a punch or nail, but do not cut out the blank just yet.

Using a router, round over the bottom only with a ¼" roundover bit.

Router Safety

DO NOT USE a router to round over edges of toy parts **UNLESS** the router is stationary, that is, attached to a router table. See Ch. 18, p 158.

2 – Drilling sequence. It is easier to drill all the holes in the body while it is still a rectangular block. Before beginning, place a piece of scrap wood under the body to prevent tear out when drilling through holes.

When drilling through holes, drill more than halfway through until the point of the bit comes out the other side. Then turn the piece over to finish drilling the hole.

Hole #1. On the side drill the through hole for the wheel axle using a $^{13}/_{32}$" diameter bit.

Hole #2. On the side drill the 1" diameter through hole to represent the cockpit.

Hole #3. On the back edge drill a hole 1 ⅛" deep using a ⅜" size drill bit. This hole is for the dowel that attaches the tail boom.

Holes #4. On the bottom drill two ½" diameter holes 1 ¾" deep. These holes are used to prepare the cavity for the rotor turning mechanism.

Hole #5. On the bottom use a 1 ¼" Forstner bit to enlarge the cavity to a depth of 1 ¾". This hole is for the rotor turning mechanism.

Drilling an Interrupted Surface

A Forstner bit is capable of drilling over another hole (see Chapter 19, p. 167).

Hole #6. With a $^{13}/_{32}$" bit placed in the center of the 1 ¼" hole #5, drill all the way through the body.

3 – Chisel out the cavity. Following the outline given on the bottom view of the body in Figure 17-3, use a hand chisel to enlarge the parts of the cavity for the rotor turning mechanism that were not cut out by drilling holes #4 and #5. The entire cavity depth should be 1 ¾". Use a chisel to smooth out the bottom of the cavity.

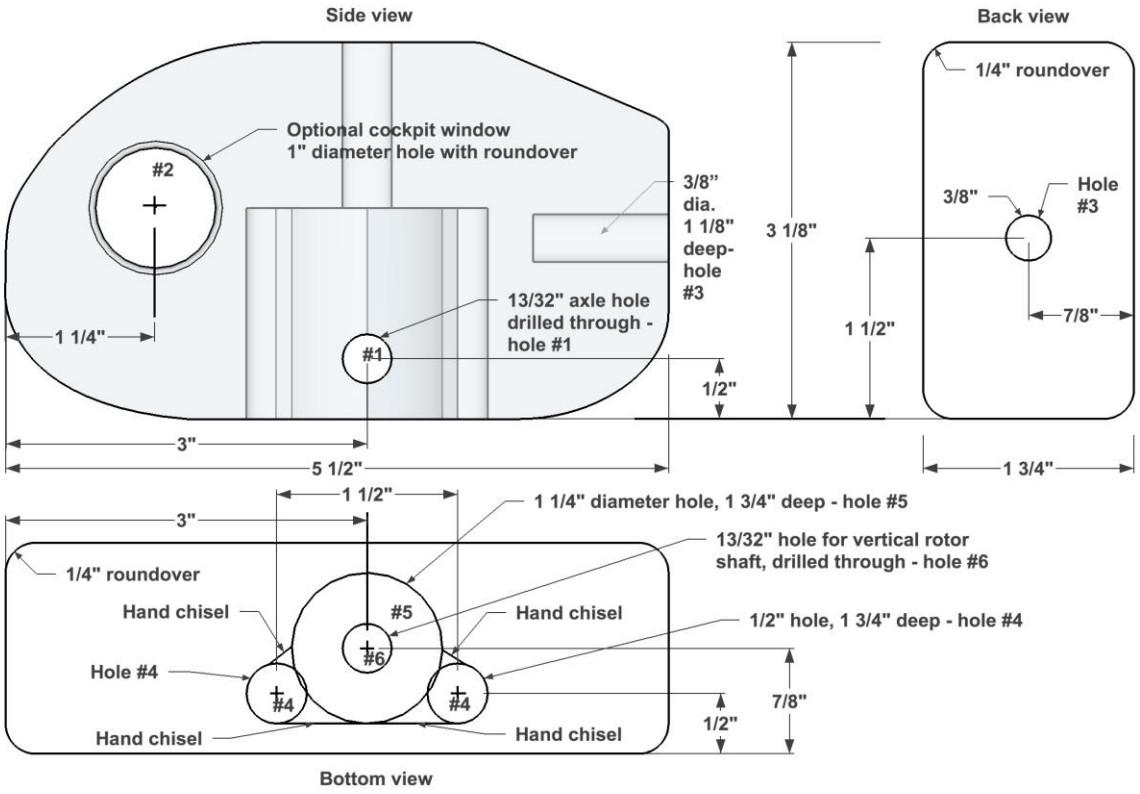

Figure 17-3. Helicopter Body (not actual size)

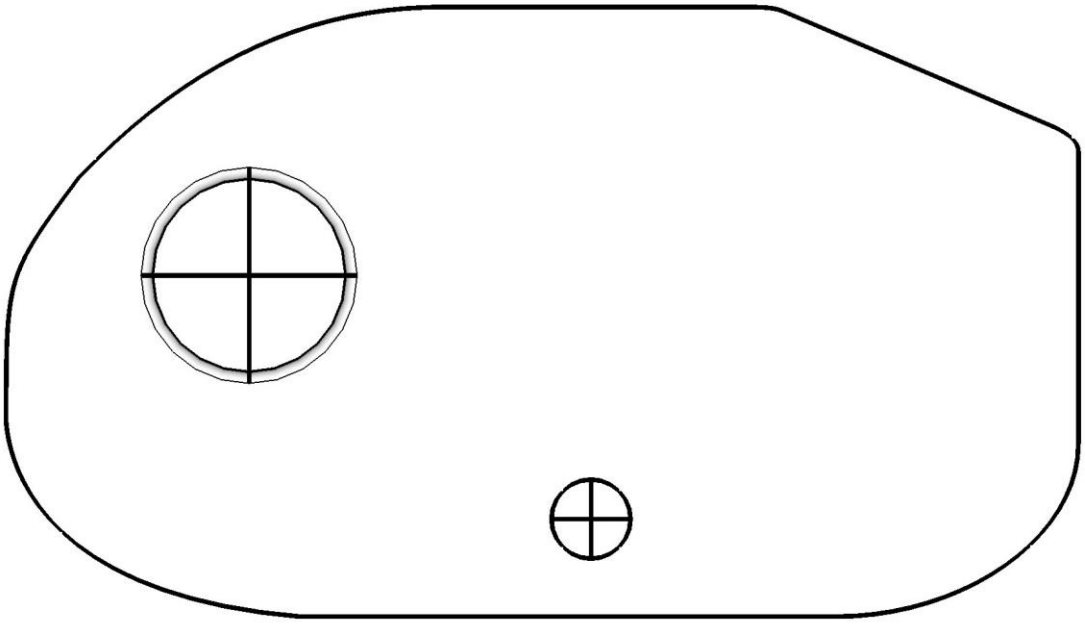

Figure 17-4. Helicopter Body Template (actual size)

Shaping Body

1 – Trim the rectangular blank. Cut out the body of the helicopter following the outline of the body previously drawn on the rectangular blank. When cutting the block, stay just outside the outline.

2 – Sanding. Finish shaping the body by sanding to the outline.

3 – Round over edges. All the remaining edges of the body should be rounded over to an approximate ¼" radius. Do this by hand since the drilled holes will prevent a router bearing from running smoothly around the body.

4 – Finish sanding. Sand all surfaces and the rounded over edges to 150 grit sandpaper.

Wheel Assembly Parts

1 – Wheel axle and wheels. Cut a ⅜" diameter dowel to a length of 5 ¼".

The 1 ¾" diameter helicopter wheels have a ¼" center hole that needs to be enlarged to fit the ⅜" dowel, which will be glued into this hole. Before enlarging this hole, it is advised to drill a test hole in a piece of scrap wood to determine the best size drill bit to use to get a good glue joint for the piece of ⅜"dowel used for this project.

Many ⅜" diameter dowels are not exactly ⅜". A $^{25}/_{64}$" diameter bit will often work better than a ⅜" drill bit. Whichever bit is used, it should be a twist bit. Such a bit will automatically center in the ¼" hole.

Jig to Drill Circular Parts

Use the drilling jig described in Chapter 19 (p. 170) to hold the wheels to enlarge their center holes.

2 – Wheel spacers. Cut two ¾" diameter dowels 1 ⅛" long. See Figure 17-2. Mark the center of one end of each dowel, then center punch the center as accurately as possible. Drill a $^{13}/_{32}$" hole through each dowel to form a spacer. Use the jig referred to above to hold the dowels for drilling these center holes.

Rotor Shaft Assembly Parts

1 – Vertical rotor shaft. Cut a ⅜" dowel 3 ¼" long.

2 – Horizontal drive wheel. This wheel should be purchased. It is too small to make safely. To purchase this wheel, see the list of part numbers in the cut list.

The wheel should be 1" in diameter and $^{5}/_{16}$" to ⅜" thick. Drill a hole in the center in which the ⅜" rotor shaft will be glued. Use the jig for drilling circular parts to hold this wheel for drilling. Select the proper size drill bit as described in the previous section. The wheel will already have a ¼" center hole. Use an appropriate size twist bit to enlarge this hole.

3 – Vertical drive wheel. Use a purchased wheel for this part - a 1 ¼" diameter treaded wheel, ½" thick. This wheel comes with a ¼" center hole.

Enlarge the center hole using an appropriate size twist bit that will enable the hole to accommodate the ⅜" axle. Next drill a $^{3}/_{16}$" hole half way through the side to the center of the wheel for the drive wheel locking pin (see Figure 17-2).

Set aside these rotor shaft parts for now.

Tail Boom Assembly

1 – Tail boom. Cut a piece of hardwood ⅞" square by 6" long (see Figure 17-5). Round over the four 6" long edges to a ¼" radius.

2 – Shaping the boom. Make the 30-degree angle cut on the end of the boom (30 degrees from the horizontal). The cut should begin midway up the back side of the boom at about ⅜" from the bottom.

A straight-forward way to do this is to first mark the cut as shown in Figure 17-5, then bandsaw or hand saw the cut just outside the line. Finish with sanding to the line with a stationary disk or belt sander, or sanding block.

3 – Drill holes in boom. Use a punch to mark the hole locations. The following holes should be drilled with a brad point bit to achieve a square bottom and a good fit for the dowels that will be glued into the holes.

Drill two ½" diameter holes in the boom ½" deep – one for the tail wheel strut centered on the underside of the boom 1 ½" from the end where the 30-degree cut was made, the other for the tail rotor support arm centered on the 30-degree cut and drilled perpendicular to this cut.

Next mark the center of the end of the boom that attaches to the body. Drill this hole for the glue dowel 1 ⅛" deep with a ⅜" bit (see Figure 17-5).

The dowels might need to be sanded to achieve a good fit in the holes drilled above. An alternative drill bit to achieve a better fit for the ⅜" hole is a $^{25}/_{64}$" diameter bit.

4 – Tail rotor support arm. Cut a ½" diameter dowel 2 ¾" long. Round over one end, then use a $^{15}/_{64}$" bit to drill a through hole ½" from the rounded end. This hole is for the axle peg that attaches the tail rotor.

5 – Tail rotor. Cut out the tail rotor from a piece of hardwood stock or Baltic birch that is ¼" thick. The width and length are ⅝" and 2 ½" respectively. Round the ends of the rotor as shown in Figure 17-2. Drill a ¼" hole in the center of the tail rotor.

6 – Tail wheel strut. Cut a ½" diameter dowel 1 ¾" long. Round over one end, then use a $^{15}/_{64}$" bit to drill a through hole $^{5}/_{16}$" from the rounded end. This hole is for the axle peg that attaches the tail wheel to the strut.

7 – Partial assembly. Use a toothpick or nail to put glue into the two ½" holes in the tail boom. Wipe off any excess glue. Insert the tail rotor support arm and the tail wheel strut into their respective holes, making certain that the $^{15}/_{64}$" holes drilled near the ends of these pieces face the side of the tail boom, that is, the holes are perpendicular to the side (see Figure 17-5). Allow glue to set for about 15 minutes before the next step.

Set aside the tail boom assembly until finish is applied to all parts.

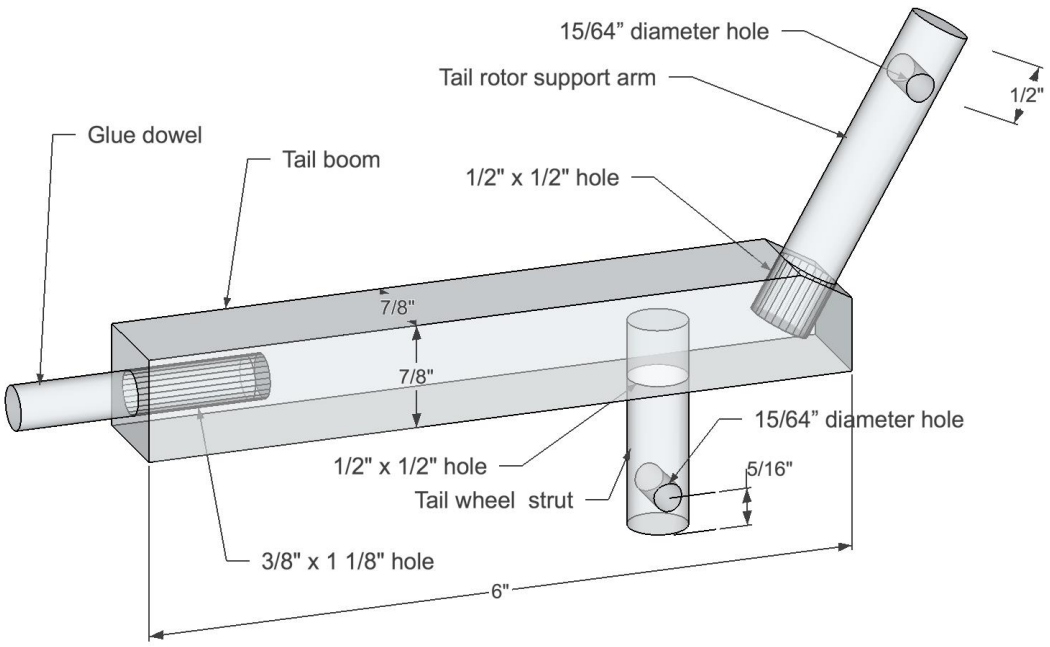

Figure 17-5. Tail Boom

Main Rotor (Propeller Blade) Assembly

1 – Main rotor (propeller). On a piece of ⅜" Baltic birch plywood 9" square draw the pattern for the propeller blades using Figure 17-7 as the template.

Cut out the blades along the outline drawn leaving $^{1}/_{32}$" to $^{1}/_{16}$", then sand to the outline. Round over all edges to a ⅛" radius, either by hand or with a router. Sand both sides and edges with 150 grit sandpaper.

2 – Main rotor hub. Mark the center of the propeller as shown in Figure 17-7 and draw lightly a 1 ½" diameter circle at the center. Cut out the 1 ½" diameter main rotor hub from ½" thick Baltic birch plywood or hardwood using a hole saw or bandsaw and jig.

Circle Cutting and Sanding Jigs

See Chapter 18, pp. 155-58,
and Chapter 20, pp. 178-79.

Alternatively, purchase a 1 ½" wood slab wheel (see cut list for the part number). Sand the rotor hub with 150 grit sand paper, then mark the center of the hub.

3 – Assemble. Glue and clamp the rotor hub to the propeller on the spot where the 1 ½" circle was drawn on the main rotor.

Once the glue has set, use a twist bit to drill a hole in the center of the hub for the ⅜" vertical rotor shaft. Test whether a ⅜" diameter bit or one slightly larger or smaller is best to provide a good glue joint in this hole. Drill almost through the hub, but not all the way (see sectional detail, Figure 17-7).

Whether made or purchased, the hub will likely already have a ¼" center hole. The twist bit used to enlarge it will automatically center in this hole.

Finish

1 –Seal. Apply de-waxed shellac to the outside surfaces of the body.

Also apply shellac to the following parts: the helicopter wheels and spacers, the tail boom sub-assembly (tail boom plus tail rotor support arm and tail wheel strut), the tail wheel, the head of the tail wheel axle, the tail rotor, the head of the tail rotor axle, and the main rotor assembly.

Do not apply shellac to the vertical rotor shaft, the horizontal and vertical drive wheels, or the wheel axle.

To prevent getting finish on the tenons of the two axle pegs, wrap them with painter's tape. Once the shellac is dry, use a fine sanding pad to remove any raised grain by lightly sanding all the parts that have been sealed with shellac.

2 – Clear coat. Apply one or two coats of a semi-gloss or gloss clear finish such as water-based polyurethane or another child-safe clear finish to all the parts sealed with shellac.

3 – Ream out holes. Once the finish is dry, ream out holes to clean out any sealer or clear coat that has gotten into them. This will help to assure good glue joints or clean holes for rotating parts.

Reaming out Holes

See Chapter 19, p. 169.

Assemble

1 – Complete tail boom sub-assembly. Attach the tail wheel to the tail wheel strut. To do this put glue into the $^{15}/_{64}$" hole in the strut, wiping off any excess glue from the surface of the hole.

Next place the tail wheel on the tail wheel axle (the $^{7}/_{32}$" axle peg). Put a washer and spacer between the wheel and strut to allow for easy rotation of the wheel,[37] then insert the tail wheel axle into the hole in the strut.

In a similar way, attach the tail rotor to the tail rotor support arm by gluing the tail rotor axle (the $^{7}/_{32}$" axle peg) into the support arm. As with the tail wheel, use a washer and spacer.

Finally, glue the ⅜" glue dowel into the end of the tail boom, allowing it to protrude about 1". The tail boom sub-assembly is now complete.

2 – Drive mechanism assembly. Verify that the vertical rotor shaft fits into the hole in the center of the horizontal drive wheel to make a good glue joint. If not, adjust the hole or sand the end of the shaft.

Next cut a piece of 100 grit sandpaper into a 1" circle and glue this circle to one side of the horizontal drive wheel.

Put glue into the center hole of the horizontal drive wheel opposite the side on which the sandpaper was glued. Then insert the vertical rotor shaft so it is flush with the sandpaper.

[37] The plastic clip used to close the plastic bag of a loaf of bread or a piece of cardboard from a cereal box make ideal spacers.

Once the glue has set, install the ⅜" vertical rotor shaft with drive wheel attached through the $^{13}/_{32}$" vertical hole in the body of the helicopter. Verify that the horizontal drive wheel clears the cavity walls by at least $^{1}/_{16}$" in all positions when in the bottom of the body. If this is not the case, chisel out more of the cavity.

3 – Trial wheel assembly. Assemble but do not glue the wheel axle, two spacers, and two wheels through the body of the helicopter. Check the amount of extra axle length. The goal is to have a $^{1}/_{16}$" gap between the spacers and the helicopter body. If the gap is more than $^{1}/_{16}$", trim the axle. If the gap is less than $^{1}/_{16}$" shorten the spacers.

4 – Attach one wheel. Disassemble the wheel assembly, and glue one wheel onto one end of the axle. To do this put glue into the hole in the wheel and push the axle through the hole from the back of the wheel until it is flush with the front of the wheel. Wipe off the excess glue.

5 – Attach drive wheel. Once the glue has set, slide the vertical rotor shaft with the horizontal drive wheel attached into the cavity and through the $^{13}/_{32}$" in the helicopter body. See Figure 17-6.

Next put a spacer onto the wheel axle and slide the axle with wheel and spacer through one side of the body, while holding the vertical drive wheel so that the axle passes through it. Adjust the vertical drive wheel so that there is a $^{1}/_{16}$" gap between it and the side of the cavity and the $^{3}/_{16}$" hole in the edge of the vertical drive wheel is perpendicular to the bottom of the helicopter body.

Using a $^{3}/_{16}$" drill bit in a hand drill, and the $^{3}/_{16}$" hole in the drive wheel as a guide, drill through the wheel axle and through the other side of the vertical drive wheel.

6 – Test main rotor assembly. Cut the $^{3}/_{16}$" diameter drive wheel locking pin to a length of 1 ⅛" – slightly shorter than the diameter of the vertical drive wheel. Insert the locking pin through the hole in the vertical drive wheel, into the wheel axle, then into the other side of the vertical drive wheel. **Do not glue it in place** at this time.

Place the main rotor assembly onto the vertical rotor shaft extending above the top of the helicopter body.

Test that the main rotor turns as the helicopter wheels turn. If not successful, identify what prevents the main rotor from turning and make corrections.

If the test is successful, remove the locking pin by using a drift punch or the head of a finishing nail to push it out of the hole in the vertical drive wheel and pliers to pull it out.

7 – Attach sub-assemblies to body.
Put a small amount of glue on the locking pin and insert it into the vertical drive wheel, through the wheel axle, and into the other side of the vertical drive wheel, thus attaching the vertical drive wheel to the axle. **Note**: Once the locking pin is glued into place it is very difficult to make corrections to the movement of the main rotor, so it is critical you are satisfied with the test performed in step 6.

Insert the second spacer onto the other side of the wheel axle and glue the second 1 ¾" helicopter wheel in place.

Next, attach the finished tail boom sub-assembly to the helicopter body by putting glue into the ⅜" hole in the rear of the helicopter body and attaching the sub-assembly.

Finally, put glue into the hole in the main rotor hub and attach it to the vertical rotor shaft protruding from the top of the helicopter.

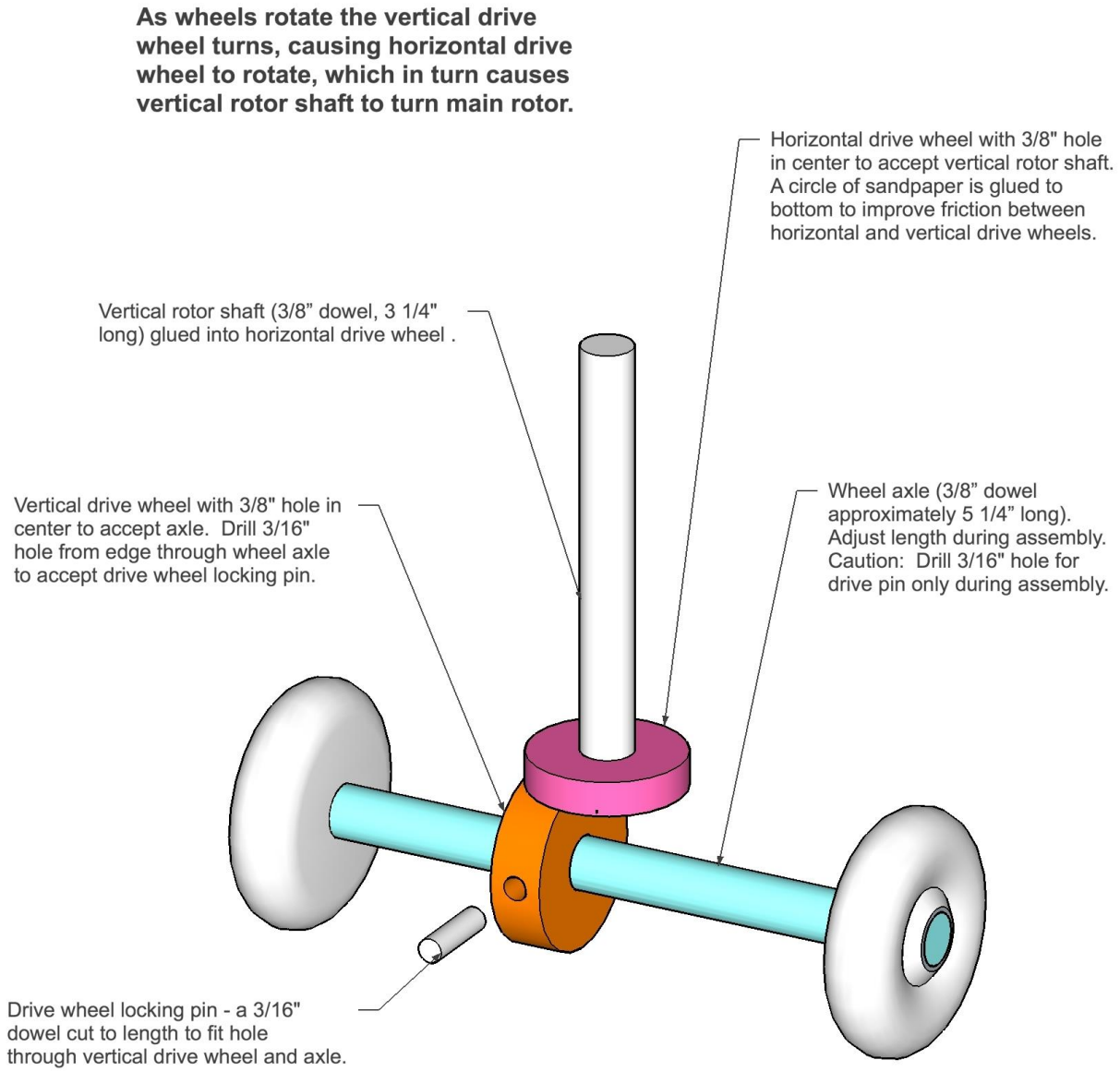

Figure 17-6. Drive Mechanism

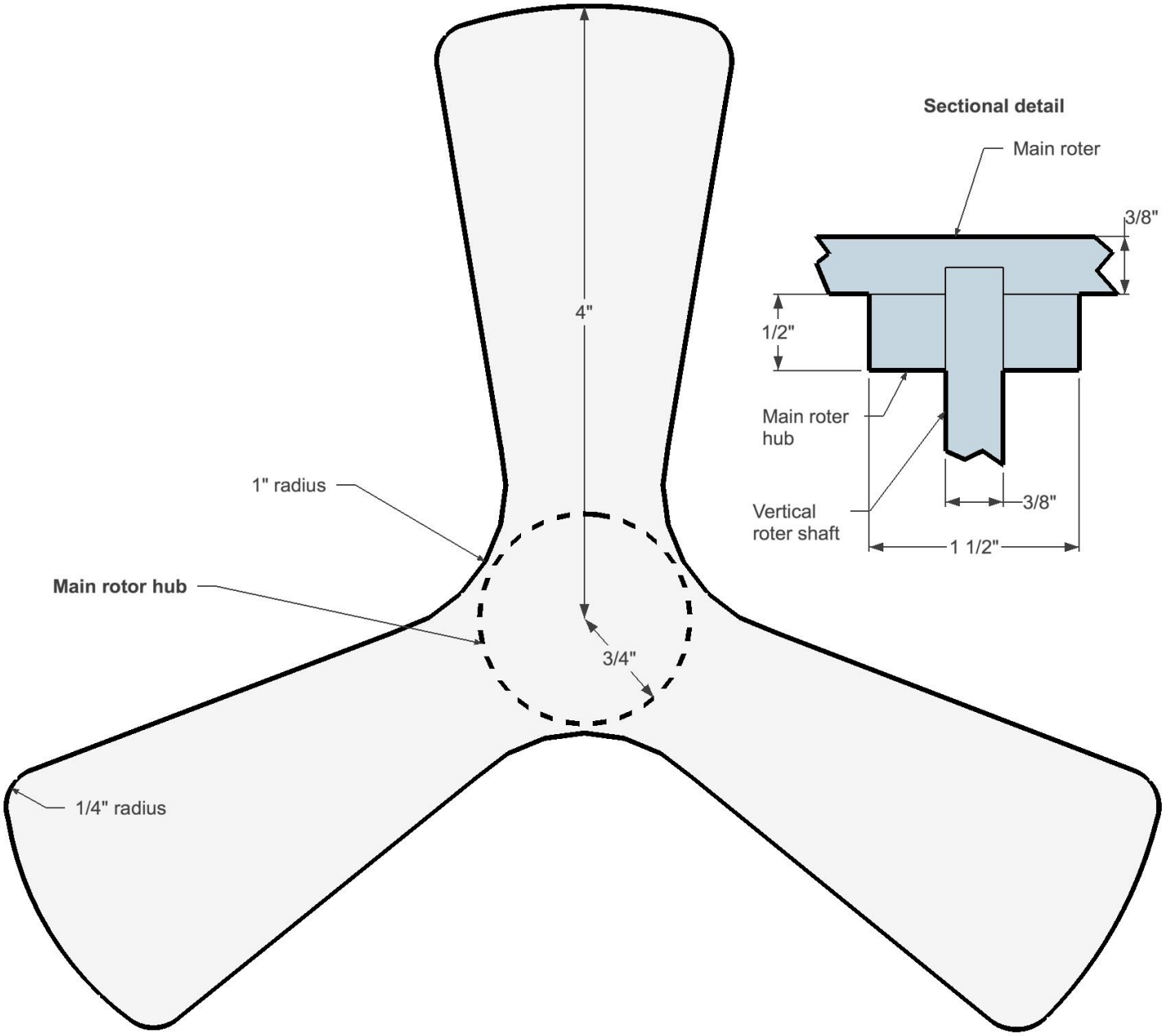

Figure 17-7. Main Rotor Template