DE HAVILLAND DHC-600 TWIN OTTER 480
BY IVAN PETTIGREW
CONSTRUCTION NOTES

The Twin Otter has a lot to offer in terms of being a good design for an electric R/C model. The long moment arm makes for good stability and the design of the undercarriage is excellent for a model. With the layout of the design it is almost impossible to break props or bend a propeller shaft. This model started life in a larger version with a Span of 84 inches which was powered by Magnetic Mayhem racing car motors or other motors in the so called “Speed 600” size. Another model that has been powered with the Magnetic Mayhem motors is the Short Sealand flying boat. When the Magnetic Mayhem motors became difficult to purchase, the Sealand was reduced in size and fitted with Speed 480 motors. It has been an extremely popular design and in some ways performs even better than the larger model. As a result, the Twin Otter model has been downsized to 80% of the original size. This size certainly makes for easier transportation.

FUSELAGE

The fuselage is a simple framed up box with bulkheads added to the top and bottom. First build the two sides of the fuselage over the plan using the shaded sticks as a guide. The longerons and vertical cross pieces are mostly 3/16” x 3/16” inch sticks except where noted otherwise. Notice that the top section of the fuselage from the nose block to the rear of the cockpit forms the top of a hatch which is removable to give access to the battery and nose gear. This section includes the cockpit windows, and is built later on when the rest of the fuselage has been assembled. Join the two sides of the fuselage together with 3/16 x 3/16 sticks. Mount bulkhead 10T in place and glue the 3/16” x ¼” longerons in place that run from the top corner of 10T to the tail. Now glue in the 3/16” x 3/16” vertical sticks and cross pieces that are shown at each bulkhead station. Note that there are 1/8” x 1/8” doublers on the inside of the top longerons from #5 to #13 bulkheads. The top of the fuselage is flat in this area, so these doublers allow for rounding the corners of the fuselage and avoiding the square box look about it. The top bulkheads are now attached to the crosspieces on the rear part of the fuselage and the top is sheeted with 1/16” sheet balsa.

The bulkheads are next added to the bottom of the fuselage, but when sheeting the bottom, leave the space between #8B and #9B open until the undercarriage is mounted. The two major stress areas in the fuselage are the wing mount and the main landing gear mount. This is the reason for additional doublers and gussets in these areas. The Plywood plate used for mounting the undercarriage needs to be well glued to the bottom longeron. When the undercarriage legs have been bent to shape and assembled, they should be screwed to the plywood mounting plate and the sheeting completed between bulkheads 8B and 9B. Do not use wire any thicker than the 3/32” specified for the nose wheel. Be sure to put the “crank” in the leg where it comes out of the bottom of the fuselage. This provides some castor for steering, but the main advantage is that, as it arcs backwards when bumps are hit, it also arcs “upwards,” thus absorbing the bump.
The “battery hatch – cockpit” is built in place. Use thin plastic like “cling wrap” between the fuselage and hatch cover to avoid it being glued to the fuselage longerons.

The battery platform should be left until the model is completed and checked for C of G location. If the model is built with the tail too heavy, the battery platform may have to be moved slightly forward. If it is planned to use lighter Li-Poly cells, the battery platform will certainly have to be moved forward to get the correct C of G location at the main spar. Do not check the battery location for C of G until the tail surfaces have been covered.

TAIL SECTIONS

The tail surfaces have a symmetrical section. A deeper spar in a tail built like this is stronger than in a flat tail surface, and warps can be controlled better. Before starting to assemble the tail surfaces, the main spars should be made and hinged so as to get a good fit. To ensure smooth airflow over the tail surfaces, make sure that the edges of the spars are flush. The plan shows the two elevators being joined by a wire, but they can be built in one piece with the spar continuing through from one elevator to the other. In this case it is wise to put a thin hardwood doubler on the spar where it is joining the two halves of the elevator. The tail surfaces are of conventional construction, but the fin may be built in place by starting with the spar being glued to the rear of the fuselage. Notice that the spar (post) for the fin goes right down to the bottom of the fuselage.

In constructing the fin, notice that F2 acts like a platform for the stabilizer to sit on, so it should be well secured with gussets. Rib F2A further secures the stab. Do not glue F2A in place when building the fin, or it will not be possible to slide the stab through the slot. Glue F2A in place only after the stab has been attached to F2, but for convenience in handling the fuselage, it is often easier to leave the mounding of the stab until most of the fuselage has been covered. The area from F1 to F2 should be covered with 1/16" sheet, the grain running vertically. Do this on one side only until the elevator and stab have been fitted and the antenna installed. To avoid the sight of an external antenna, it can be run down the inside of the fuselage and up the inside of the fin. A connector can be put in the radio antenna about three inches from the radio.

WING CONSTRUCTION

The wing is built in one piece. If it is too large for transportation, the wing could be built in sections. Joining the wing at the centre is NOT the way to go because of the stress at the centre of the wing, and complexity of the motor wiring etc. Wing joiners could be built in the usual manner at the point where the ailerons start. There is not so much stress out there and it is easy to hook up the ailerons by placing the bell cranks just inboard of the break and putting the aileron control horn right at the inboard end of the aileron. The aileron pushrods cross the ribs between these two points at a slight angle. This builder prefers to build a wing of this size in one piece because of simplicity, weight saving and strength. The basic airfoil is a Selig 7055, but outboard of the aileron break it uses a NACA leading edge cuff to reduce tip stall tendencies.

The flaps are optional. With such a light wing loading, flaps are not really necessary on a model like this. They are a lot of work, and add some weight. Generally speaking, flaps do not make it easier to land a model plane. A light model does not have very much inertia, so with the extra drag of flaps lowered, speed bleeds off quickly in the landing flare, and the stall comes more abruptly than with no flaps. I have put flaps on models in the past, and have usually ended up using them very little. Their main purpose was novelty value. But the slotted flaps of the Twin Otter do slow the landing speed considerably, and make slow flight very impressive. The flap extension is limited to 20 degrees. Beyond that amount, flaps do not produce any significant increase in lift, but do add a lot more drag. With a model, the additional drag is not really necessary, and it is this drag that makes the landings more difficult, so it is best to just use 20 degrees of flap for landing, and an optional 10 degrees for take off. When in slow flight with flaps extended, there is often a tendency for a model to yaw. It is most important that this yaw is controlled with the rudder. Flyers who don't know how to use the rudder in flight should avoid using flaps. The use of aileron to control yaw in slow flight is a "No, No," and will usually aggravate the problem.

The wing construction is a little unconventional in that a full depth 3/32" sheet balsa spar is continuous throughout the wing. The ribs are cut where they meet the main spar, and are butted to the front and rear surfaces of the spar. Cut the main spar from 3/32" sheet balsa and splice the pieces together over the plan so that the correct dihedral angle is built in. Now glue the 1/8" x 3/16" hardwood strips to the top and bottom surfaces of the spar as indicated. These strips should be bass (basswood) or spruce. Notice that they do not go all the way to the tip. In other locations where bass is stipulated, spruce or other hard woods may be used.

Cut all the ribs in two at the point where they join the spar. Build one wing panel first by pinning the spar on its edge over the plan, the spar for the other half of the wing being raised slightly because of the dihedral. It is easiest to start by gluing the rear part of each rib in place first, then attaching the secondary spars. Next add the trailing edge to the centre section, and to the inboard part of the wing panel if not fitting flaps. Now glue the front part of each rib in place and then the first inner strip of balsa which forms part of the leading edge. The outer strip that completes the leading edge is not added until the sheeting has been applied to the top and bottom surfaces of the wing from the leading edge back to the main spar. When one section of the wing has been assembled, it is propped up a little so that the lower edge of the spar for opposite wing is flat on the work bench. The second section of the wing is then built in the same manner as the first. At this point the wing will still be very floppy. Some call it "Ivan's spaghetti." Be patient, and please resist the temptation to add wood.

Sheeting is now applied to the lower surface of the wing from the leading edge to the main spar. It should be done in two sections, one inboard of the leading edge break, and the other outboard. At this point the wiring may be installed for the motors, but it is possibly better to leave the wiring until later, since it makes it easier to sheet the upper surface without the wire in place and protruding from the bottom of the wing. At least the holes for the motor wiring should be drilled at this point in the nose ribs between the centre section and motor bay. The wiring should be twisted to reduce the risk of electrical interference with the radio. It will be noted that the wing is still not torsionally strong, meaning that it can easily be twisted. In other words it is still "spaghetti." After the sheeting is applied to the upper surface of the wing it will be extremely rigid and difficult to twist. Hence it is very important when applying the sheeting to the upper surface, to weight that section of the wing down on a surface that is perfectly flat. There should be no washout from the wing root to the start of the aileron (leading edge break), but from that point to the tip there should be 1/4" washout. So the inboard top surfaces of the wing from the root to the leading edge break should be sheeted first with the wing weighted down perfectly flat. Note that the flat bottom section of the inboard ribs is that part from the main spar to the secondary spar.

Next apply the sheeting to the top of the outboard section with the rib at the leading edge break weighed down flat, but the trailing edge of the tip rib propped up ¼" to give the correct wash out. If you really want to be able to do tip stalls and spins, don't put in any washout. As set up in the plans with regard to washout, C of G location and elevator throw, this model will NOT tip stall or spin. The best it will do is a lazy spiral. The remaining balsa strips that form the leading edge are now glued to the ones in place and contoured to shape. Finally, sheeting is added to the part of the centre section aft of the main spar. If the motor wiring was not installed before sheeting the wing, it is easily accomplished now by cutting out a narrow strip of the lower covering where the wires are to be located. If the cut is angled a little, wider at the top, it is very easy to glue the same strips back in place after the wiring is installed. The ailerons are installed as shown on the plan. For accuracy in building the ailerons, the 1/8" spar (leading edge) of the aileron can be hinged to the wing first, then the ailerons built with the spar attached to the wing. It pays to really work at getting the ailerons to be a flush fit with the wing so that drag is at a minimum. That is the advantage of fitting the aileron spar to the wing first and trimming it to the exact size before building the rest of the aileron.

The flaps are built independently, the leading edge being shaped from ¼" sheet balsa. The plywood brackets that mount the flaps are glued to the wing and flap ribs. In order to keep the covering neat, it is necessary to put sheet gussets around the area where the mounting brackets come out of the wing and flaps. Before locating the flaps in place and drilling the holes at the hinge point, be sure there are no warps in them. Any twist or warp in the flap will make a difference to the correct location of the hole that forms the hinge point. If there is a twist in a flap, it is best to cover it and shrink the covering material so that it keeps the flap straight. It can then be mounted. If more flap deflection is desired than is available from the outer hole of the flap servo arm, deflection can be increased by using the inner hole of the input arm of the bellcrank, and the middle or outer hole of the output arm where the pushrod to the aileron is attached. A regular servo has been found to be satisfactory for operating the flaps. It has not been necessary to use a 180 degree retract servo, and some of those available are not suitable for partial flap operation since they will not stop at an intermediary point.

A small amount of the lower sheet covering has to be removed where the motor bearers are to be located. Start by gluing 2 inch long triangular strips to the rear face of leading edge and front face of the spar at the location shown, then attaching the hardwood bearers that form the motor mounts. Now the nacelle bulkheads are glued in place, and the nacelles planked with 1/16" sheet balsa. The strips of 1/16" planking on the lower part of the engine nacelle should not be more than ½" wide. Notice that the front of the planking comes to the mid point of the 1/4" thick bulkhead, N1. The shoulder that is left on the front half of this bulkhead holds the shape of the

cowling and keeps it in place. Notice too that a passage for cooling air to pass through the motor compartment is formed by cutting holes in bulkheads N1 and N3, and by leaving a triangular section open on the inboard side of the engine nacelle to the rear of "N3."
The engine cowlings are built in place with the motors installed. Before starting the construction of the cowling, small strips of hardwood are glued to the front surface of N-2, one at each side. These are for locating the #2 wood screws that hold the cowlings in place.

Next the nose blocks are made, but the hole for the propeller shaft should at this point be made just large enough for the nose block to be a snug fit on the prop adaptor. If the motor is slid back slightly from its correct position, the back plate of the prop adaptor will hold the nose block in place while the cowlings are being built. Later the hole for the propeller shaft can be enlarged. With the nose block held in place by the propeller adaptor, start making the cowls by cutting out the inner and outer side panels. These are attached to the hardwood mounting strips with the two locating screws, then glued at the front to the nose block. Next apply the top and bottom parts of the cowling, gluing these to the nose block and adjacent side panels, but not of course to N-2.

Depending on the kind of balsa that is used for the curved upper and lower parts of the cowling, it may have to be dampened on the outside to help it bend. When the glue is dry, take out the screws and remove the cowlings. Now the hole in the nose block for the propeller shaft can be enlarged to give adequate clearance and the motor slid forward to its correct location. Before covering the cowlings, small washers should be made from 1/64 ply and placed under the heads of the #2 screws that hold the cowlings in place.

CONTROL THROWS

Aileron differential is achieved by making the control arm on the aileron as shown on the plan, but the location of the aileron control horns is important too. If the horns are too far forward they will reduce the differential. Likewise, the differential is increased by placing the horns further aft. Poor aileron design makes for problems in many models because of the adverse yaw that is inherent at larger angles of attack, such as in slow flight. Two things are done in the design of the Twin Otter to reduce this problem. Frise ailerons are used, and a substantial amount of differential is used in the aileron linkage. This makes the ailerons much more responsive at slower speeds. Be sure to support the pushrods in the fuselage so that there is no flexing when under load. This is not a problem in the wing where the ribs hold the pushrods in place.

In multi motor electric models, there is a risk of problems with radio interference from motor brush noise and the increased length of wiring used for the motors. While it is always recommended to put a Schotky diode across the terminals of each motor when they are wired in series, it is not so critical in this application where the motors are wired parallel. The normal capacitors should of course be used across the motor terminals, whether or not Schotky diodes are used. The wires carrying current to the motor should be kept touching each other, and twisted about one turn to the inch. Wire of at least 16 gauge should be used from the motor to the point where it joins the wire from the opposite motor since it is only carrying about 15 amps. But from the junction point of the wires to the output of the speed control there will be 30 amps, so heavier wire of at least 13 gauge should be used. Keep the length of wire from the junction point to the motors the same for each side. If they are uneven, the motor with the shorter wire will get a higher voltage and run slightly faster. The radio and servos should be kept as far as possible from the motors and motor wiring, but this is taken care of with the layout shown in the plans. Servo leads must be kept short. Do not use outboard servos for the ailerons. These would require long leads running along the wing parallel to the motor wiring, and they would be very prone to picking up interference. At the low airspeed of this model, one standard servo is ample to operate the ailerons.

COVERING AND FINISHING

Because of the type of construction used in the wing, it is very difficult to correct any warps in the wing once it is covered. Hence, the wing should be checked before covering. It there are warps, the sheeting on the front half of the wing should be dampened, and the wing weighted down in the correct position. Leave it overnight to dry. Most of the airframe on the prototype is covered with low temperature film. Besides being lighter than most high temp films, it is less likely to warp the light weight control surfaces. Transparent Clear Monokote is excellent for windows and is great for the windscreen of models like this where the panels are flat.

MOTORS

There are many options regarding motors. Some modelers will choose to go with brushless motors and they are no doubt the way of the future. The weight saving of going to brushless motors and a LiPo battery is of greater advantage in a smaller model like this than in larger models the size of the Twin Otter 600 where the extra wing area helps carry the weight of the heavier equipment. If going the brushless route, be sure to use an individual speed control for each motor. A Speed 400 brushless motor should give adequate performance, but try to match the power system to the 10 x 7 APC electric prop. Use of a smaller diameter prop, or a 10 inch prop of reduced pitch will result in a decrease in performance. Power system efficiency is a combination of motor efficiency and prop efficiency. The added efficiency of a brushless motor is often lost when a smaller diameter, or finer pitch prop is used. Fine pitch props are wonderful for 3D or slow flyers, but do not give adequate pitch speed for sport flyers like this. Also note that the figures given are for APC “electric props”. Please do not substitute with APC “Slo-Flyer” props which are very different. They may give more static thrust, but will result in a much higher amp draw and slower pitch speed.

Jamara 480 and Permax Speed 480 motors are sometimes referred to as “long can Speed 400” motors. They are not to be confused with the Graupner series of Speed 480 motors which have a different configuration and thicker shaft, apart from being quite a bit more expensive. Because the diameter of the motor can and the shaft thickness of the Jamara 480 and Permax 480 motors are the same as for Speed 400 motors, they use Speed 400 gearboxes.

The Jamara motors are available from John Swain of www.fanfare.f9.co.uk at Eight Pound each. He sends overseas orders by airmail at a reasonable cost, and can supply the 4.1:1 ratio MP-Jet gearboxes and 3mm “long shaft” prop adaptors that are necessary with these gearboxes

A cheaper option in N America is the Permax 480 7.2 volt motor available from Tower Hobbies at $9.50. The Permax motor does not have ball bearings and is not as efficient as the Jamara. The Permax motor has more turns of thinner wire than the Jamara, so if maximizing the performance of the Permax motor, it should be run on more cells than the Jamara, but the Jamara with its winding of thicker wire can take more amps. Because of the different number of winds, the Permax motor runs at lower RPM than the Jamara and should be used with a lower ratio gearbox.

A starting point for the Permax motor would be to run it on nine cells with a 3:1 ratio gearbox and 10 x 7 APC electric prop. There are several reasonably priced offset gearboxes available for Speed 400 motors such as the T400 3:1 BB available from Tower Hobbies for $14.99. This is the open type of gearbox shown on the plan. The MP-Jet sealed gearbox (also available from Tower under the Great Planes name) is not screwed to the motor, but the motor slides into a plastic sleeve on the gearbox. This gearbox is designed to be mounted to a bulkhead, but this is difficult in multi motor applications. The MP-Jet gearbox and motor can be mounted to the beam type mounts used in this model, and held in place with a hose clamp. But one very important thing to note is that the hose clamp must be over the black plastic sleeve of the gearbox where it fits over the motor. If the clamp was over the motor alone, the thrust of the propeller would pull the gearbox off the motor during flight.

The other thing to notice is that these 480 motors come with sleeve called a flux ring which adds to efficiency. The motors can be run with or without the sleeve. Power output will be increased by removing the sleeve, but the motor will draw more amps and heat up more. The flux ring can be left in its intended location when using the open type offset gearbox which is screwed to the motor. But with the MP-Jet type gearbox, the flux ring will have to be slid backwards a little and will block the cooling holes of the motor. A small section of the flux ring should be cut out where it covers these cooling holes. It is claimed by some that these Speed 480 motors can be run up to 170 watts input. In the applications given here the input is closer to 125 watts which is a conservative figure that results in better efficiency and longer motor life. Either of these motors can be upgraded to the use of Li-Poly battery packs with “three series” combinations. The weight saving will enhance the performance of the model considerably, but the main test is to see that the motors are not too hot at the end of a flight.

FLYING

The Twin Otter is extremely safe to fly and handles like a trainer. Flaps are not necessary for take off, but the use of half flap will shorten the run. The first landings are best done without flap. The model should be flared and held off until a nose up attitude is achieved. After floating a while it will touch down gently on the main gear. “No flap” landings are possible without the use of any power and are the easiest kind to make. A guide to getting the right speed on approach is to watch the attitude of the plane. If the nose is low when no flaps are being used, the speed is too high. If the nose is high, the speed is too low. On a power off approach with no flaps, the plane should be in a level attitude, very slightly nose down if anything. A flat, slow, no flap approach can be done in a “nose up” attitude if some power is maintained, but this should only be done in calm conditions. The wind is not as strong near the ground as it is up at the height of the approach, so airspeed has a habit of diminishing in the last stages of the approach when flying in windy conditions. If the airspeed gets too low on the approach when there is a wind gradient like this, there is not enough airspeed for a safe flare. The result can be a very heavy landing because the model runs out of airspeed and seems to drop out of the sky.

Landings are of course possible with partial or full flap. Before lowering the flaps in flight, the airspeed should be reduced. This avoids the “pitching up” that comes if the flaps are lowered while going too fast. If approaching with full flap and no power, the sink rate will be greater than when no flap is used. When it is intended to land with full flap and without any power, the nose should be kept lower than usual so that there is some reserve speed for the flare.

The more typical STOL approach is a little flatter with some power applied to maintain airspeed, and control the descent rate. In this type of approach the plane does not have to be kept in such a nose down attitude as when no power is used, but the power should be kept on through the flare until the model is in a slightly nose up attitude. In windy conditions it is best to land without flaps. A plane with tricycle undercarriage must never touch down on the nose wheel first. If this happens it is a sign that the landing speed is too high. The result will be a series of skips, and the nose gear may be stressed beyond its limits. The plane should be slowed until it touches down on the main gear first with the nose wheel slightly off the ground. To achieve this, it is important that the undercarriage is correctly rigged so that while the plane is sitting at rest on the ground, there is a slight angle of attack to the wings. This angle is even more important for the take off.

Without any angle of attack while taking off, the plane will gather excessive speed without much lift, then suddenly jump into the air when the nose is lifted. With the correct angle of attack, a plane should smoothly lift off automatically as soon as it is safely traveling a little faster than the stall speed.

LONG and SHORT NOSES

Some builders may wish to fly the model on floats. In real life there are two types of noses on the Twin Otter. This model has the long nose. The long nose version is not generally approved for floats, but there may be exceptions where extra fin area is added to the tail to compensate for the greater side area of the long nose. If the builder wishes to make this model like the short nose version, the nose wheel location does not need to change. The nose is only shortened forward of the bulkhead where the nose wheel is attached.

Have fun flying your Twin Otter.

SUMMARY

DHC-6 Twin Otter 480. Dec 2005. Scale 1/12 Span 67.5 inches. Wing area 612 sq.in. Length 52 in. Airfoil: Selig 7055 with leading edge cuff on outboard sections. Flies on eight to ten cells. Weight with eight CP-1700 SCR nicads is 60 ounces giving a wing loading of 14.1 oz/sq.ft. Two Jamara Speed 480 HS BB motors, wired parallel. MP-Jet 4.1:1 gearboxes with 10 x 7 APC electric props. Static current draw is 23 amps (11.5A to each motor), giving a static thrust of 30 oz at 5,900 RPM. Weight given is without optional flaps. The flying weight and wing loading will be considerably less with brushless motors and a LoPo battery.

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