S-45 SHORT SOLENT Mk IV
BY IVAN PETTIGREW
CONSTRUCTION NOTES
Designed for Speed 480 motors May, 2006

When the Short S-23 “C” Class flying boats were built in 1936 they were a great leap forward in the world of long range flying boats. They were followed a few years later by another civilian version, the S-30 Empire Class flying boat. In 1938 a military version, the S-25 Sunderland, went into service with the Royal Air Force and during WW II was produced in much greater numbers than any of the Civilian models. Following WW II some Sunderlands were converted for airline use and named the S-25 Sandringham. In the late forties the S-25 was stretched and fitted with much larger engines. The result was the Solent. The Mark IV was the last model produced and can be identified from the earlier Solents by the large spinners and full size windows on the lower rear deck. ZK-AMO was one of several operated by Tasman Empire Airways Ltd (TEAL) on its routes from New Zealand to Australia. It was quite a step up from the S-30s that first flew this route. The S-45 carried 35 passengers instead of 17 for the S-30, and the flight time across the Tasman Sea was 5½ hours instead of 9 hours. When the flying boats across the Tasman were replaced by land based DC-6B aircraft in 1956, ZK-AMO was transferred to Fiji from where it flew the so called “Coral Routes” to the Cook and Samoan Islands. It flew in scheduled service until 1960 when it was placed in the MOTAT Aviation Museum in Auckland, NZ. It is beautifully restored and is the only surviving Mk IV Solent in the world. Six S-45 Seaford flying boats were built for the Military as replacements for Sunderlands, but they did not go into service. They were bought by BOAC and converted for civilian use as S-45 Solents.

An earlier model of the Solent was designed with a span of 82 inches and used GWS Speed 400 geared motors. It proved to be an excellent flyer and water handling was great. This Speed 480 powered model is a scaled up version of the earlier Solent 400 model and has a wing span of 99 inches. When comparing the length of the fuselage to the wing span, the Solent has a longer fuselage than most flying boats. The fuselage of this model is slightly longer than the fuselage of the Mars (Ivan’s Plans 2001), but the span of the Solent is only 99 inches which is considerably less than the 120 inch span of the Mars. This in effect means that the Solent has a long moment arm which results in very smooth flying qualities. It also has a long hull which makes it very safe when operating in rough water.

Before starting construction, a few options need to be considered. Some builders may be able to handle the wing in one piece, but the prototype was built with the wing in three sections. The outer panels are detached from the point where the ailerons start just outboard of the engine nacelles. The easy way to connect the ailerons then is to put the aileron horn right at the inboard end of the aileron, and the aileron bell crank in the last bay of the main section of the wing, just behind the nacelles of the outboard motors. The aileron pushrods can then be run diagonally across the ribs where the outer panels join the main wing. Removable wing panels add weight and may sacrifice strength, but they certainly make for convenience in building, storage and transportation. It could be feasible to make just one wing panel removable, but in that case, a small weight should be added to the opposite wing to provide balance. A snap faster under the wing holds each panel in place, so wing assembly involves closing this fastener and connecting the clevis on the control rod (from the aileron servo) to the aileron horn. On the plan of the wing, the right wing shows the design to use if removable panels are used. The left wing shows the layout if building the wing in one piece.

The Solent has a very high fin and rudder, so to help with the transportation, the prototype was build with the upper half being detachable. This again is optional.

The plan of the right wing shows the mounting of the Multiplex Permax 7.2 volt motors that were used in the prototype with MP-Jet gearboxes. These motors are sometimes referred to as “long can Speed 400” motors. They have the same case diameter, mounting hole spacing and shaft diameter as regular Speed 400 motors, so any Speed 400 gearboxes can be used. These remarks do not however apply to Graupner Speed 480 motors which have a larger case diameter and thicker shaft. The plan of the left wing shows the mounting of the type of gearbox that fastens on to one single stick. The Permax 480 motors could be used for instance on GWS Speed 400 gearboxes which would mount in this manner, but the sealed MP-Jet gearboxes are quieter and more substantial. Some builders may wish to install Speed 400 brushless motors and they could be installed with the GWS type mount. The Permax 480 motors are wired parallel and the model performs adequately on ten 3300 mAh NiMH cells. Performance is enhanced by using 11 cells or 3 series Li-Poly cells. With the gearing and prop size indicated, eleven cells would probably be excessive if applied to just one 480 motor, but each time an additional motor is added in parallel, it almost needs an extra cell to compensate for the added load and resulting voltage drop. Hence with eleven cells to four motors, each motor is working at far less than its maximum capability. The model flies “scale like” on nine cells. But few modelers know what “scale performance” really is. A PBY Catalina at gross weight had a maximum rate of climb of 660 feet a minute; less than a Cessna 150. The ESC should be able to handle at least 40 amps, but if using BEC, watch that you do not exceed the limit on the number of cells. With a model of this size I prefer to use a separate receiver battery.

The airframe construction is very light, but adequately strong for all flight stresses. During construction it may appear to be very flimsy. Please resist the temptation to use thicker wood than specified. When finishing details are added the weight builds up. As covering is applied the airframe will become quite rigid. Think in terms of building a park flyer. With the light wing loading of this model, maybe it should be termed a “pond flyer.” Some builders of this type of model have described the components as being like spaghetti during construction, but have been amazed at how firm they are when completed. Old timers will relate to this in how rubber powered free flight models were built years ago. Don't be discouraged if a few pieces break during the handling of the airframe during construction. Be patient; the end result will be fine.

The sizes given for the trailing edge stock may be non standard. That is because it suits the airfoil shape better, and this builder has always shaped trailing edges from regular strips cut from sheet balsa. All the strips for the longerons etc have been cut from sheet balsa using a stripper. Looking at the typical sheet of balsa and checking the density (hardness) with a finger nail, it can often be seen that the part to one side of the sheet is harder than the other. The hard side makes for good strips which are better in quality than many of the ready cut strips that are bought. The remaining softer part of the sheets can be used for bulkheads and other secondary components.

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 shaded sticks shown on the plan. Use 3/16 square balsa cross pieces to initially join the two sides together. The top and bottom bulkheads can be attached to these cross pieces later. Take note that the sides slope inwards slightly towards the top, the width of the fuselage at the top being less than at the bottom. The top and bottom sections of the sides of the fuselage are in two sections aft of bulkhead #9. The upper sections come together at the tail, while the lower ones come together at the point of the second step.

Add bulkheads and sheeting to the curved upper surface of the fuselage. The lower semi circular bulkheads from 10C to the tail should then be added to the bottom of the upper section of the fuselage and sheeted with light 1/16" balsa. The remaining part between the upper and lower sections of the fuselage are next covered with 1/16" sheet, but before proceeding to cover this area, read through all of the instructions and get the complete picture in your mind. While the shape of the outer skin on the section of the hull from bulkhead 10c to 12c is the most challenging part of the fuselage construction, it is not as difficult as it might seem. My problem is not in doing it, but in explaining it in words that make it easy to follow.

The sides of the fuselage are just sheeted from the bottom up to a point an inch or two above the water line. This sheeting is straightforward from the nose back to bulkhead 9. To sheet the lower section of the sides from bulkhead 9 to the end of the second step, including the 3/32" balsa fillet attached to the keel bulkhead between 11C and 12C, use a single piece of 1/16" balsa. The bottom part of this sheet is glued to the side (lower section) of the secondary step. The top curls out to meet the sheeting that was earlier applied between bulkheads 10C and 12C. It is much easier than it sounds, especially if this 3" wide piece of sheet is dampened before applying. Most modellers attempting a project like this have built a low wing scale model like a Spitfire that has a gusset where the trailing edge meets the fuselage. One way to visualise this is to lay the fuselage on its side, and think of the 3/32" gusset at the end of the second step as being the gusset where the trailing edge of a Spitfire meets the fuselage. Forward of the main step, the bottom of the hull is covered with four strips. Start by attaching the outer strips as if this was a flat bottom hull. Next attach the triangular bulkheads, 1B to 6B, then the inner two strips that form the "V" section of the hull. This results in the bottom of the hull having a concave contour. This shape really helps in reducing spray and getting the model on the step promptly. The Solent will take off easily with about 80% power. Use of reduced power during take off adds much to realism by lengthening the take off run.

TAIL SECTIONS

These are of conventional construction. Notice that the spar (post) for the fin goes down through the stab to a cross pieces that is attached to the top longerons of the original "box" part of the fuselage. This adds strength to the mounting of the fin. Before starting construction of the tail surfaces, it is best to make all of the spars and hinge them carefully. Notice that the stabilizer has slight dihedral. Glue the two pieces of the stab spar together over the plan to get the correct dihedral angle. While making the first half of the stab, prop up the other end of the spar. When completed, prop up this half while the other half of the stab is built. The tail surfaces have a symmetrical airfoil surface. This type of construction adds depth to the spar which makes for more strength, meaning that the tail surface can be built lighter than if a flat surface was built. It also resists warping better than a flat surface and makes for smoother flying. Because of the dihedral in the stab, independent control rods are necessary to the elevators. It is best to use nyrods and have a "Y" junction just forward of the stab leading edge. Lightweight nyrods should always be braced at each station along the fuselage to prevent "bowing" under load.

WING CONSTRUCTION

The wing is built in one piece. The basic airfoil is a Selig 7055, but outboard of the second engine nacelle it uses a NACA leading edge cuff to reduce tip stall tendencies. The wing construction is different from the usual, but is extremely strong for its weight. A full depth 3/32" sheet balsa spar is continuous throughout the wing The ribs are cut into two pieces where they meet the main spar, and are butted to the front and rear surfaces of the spar. First cut the main spar from 3/32" sheet balsa (yes, 3/32") and splice the pieces together over the plan so that the dihedral angle is correct. Now glue the hardwood strips to the top and bottom edges of the spar as indicated. These strips should be bass or spruce. Notice that these strips terminate at different places so as distribute the stress.

Cut all the ribs in two at the point where they join the spar. Assemble one half of the wing section with the spar of the other half propped up. It is best to start by attaching the rear half of each rib, then the trailing edge and secondary spars including the one used to hinge the aileron. The ailerons may be cut out and hinged later. Next glue the front section of each rib to the front face of the spar. Notice that the leading edge consists of two strips, the inner one of 3/32" sheet balsa, and the outer one of ¼" balsa. Only the first (inner) strip should be applied at this time.

Build the other wing panel over the plan by propping up the already constructed panel to the correct dihedral angle. Notice that the main spar is slightly swept back. For maximum strength at minimum weight, the spar was not cut and rejoined at the centre line to incorporate this sweep back. The spar is so flexible, that a gradual bend is incorporated. The correct way to build the second wing panel would be to prop up the completed wing panel and sweep it back at the same time while building the second panel over the plan. An easier way though is to build the second panel as if there was no sweep back. The inboard ends of the trailing edge will be a small distance apart. When these ends are later drawn together and joined with a doubler, the correct sweep back angle of the spar will be formed. The rest of the wing is now completed including the tips. Also install the 1/8" sheet balsa strips where the tip floats are mounted to the wing. Notice the 1/16" plywood plates on the inside that are necessary to hold the attaching screws.

Sheeting is now applied to the lower surface of the wing from the leading edge to the main spar. At this point the motor wiring should be installed running along the wing midway between the leading edge and spar. No 13 gauge wire should be used from the ESC connector to a junction point inside the wing root, then No 18 gauge wire used for independent wires to the inner and outer motors. It will be noted at this point that the wing is still not torsionally strong, meaning that it can easily be twisted. After the sheeting is applied to the upper surface from the LE to the spar, the wing will be very rigid and difficult to twist. Hence it is very important when applying the sheeting to the upper surface, to weight the wing down on a surface that is perfectly flat.

The top sheeting should be applied in two stages, the first one being from the centreline out to rib #8 where the wing cuff and the aileron start. There should be no washout in this section, so the wing should be weighted down flat. From rib #8B to the tip there should be 1/4 " washout. When the wing is weighted down with this amount of washout at the tip, the sheeting is applied to the upper surface of the outer part of the wing. The remaining strip of ¼" sheet balsa that forms the outer part of the leading edge is now glued to the one in place and contoured to shape. Finally sheeting is added to the centre section and areas where the engine nacelles will join the wing.

The tip floats are built up and planked with 1/16" sheet balsa. Construction is fairly basic, especially for anyone who has built a set of floats. The upper half of each float is planked with 1/16" strips. This may seem a bit tedious, but results in beautiful compound curves. The lower end of the struts are built into the floats. The upper ends are attached to the wing with #2 screws passing through small 1/32" plywood plates that are butt glued with epoxy to the end of the struts. For getting the correct angle on these plates, it is best to screw the plates to the wing first, then with the wing resting upside down, glue the ends of the struts of the completed float assembly to these plates.

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The engine nacelles are built by first gluing the motor mount bearers in place, securing them firmly to the leading edge of the wing and the main spar, reinforced with the support strips shown on the plan. Next the nacelle bulkheads are made. Notice that there are small plywood plates glued to the rear of the first bulkhead, N1, where the cowlings attach. Before gluing the nacelle bulkheads in place, it is a good idea to make each cowling bulkhead, C2, that attaches to N1, and drill the screw holes to get correct alignment. Number the bulkheads according to the motor. The nacelle bulkheads are then glued in place and the nacelles planked with 1/16" sheet balsa. To provide for cooling air to pass through the motor, air outlets are cut on the inside wall of the lower part of the nacelles under the wing. In this location they are not noticeable to anyone except the passengers in the lower deck. The nose rings of the cowling are cut out like doughnuts, and can be of one piece of thick balsa, or laminations. They are then shaped to the correct cross section and the cowling assembled. Do this by damping the 1/16" sheet covering that forms the cowling, wrap it around to form a sleeve and join the edges with CA glue. Check the fit of the nose bulkhead C1, and also C2. Since the cowl is slightly tapered, these should be slid in from the rear. If the cowl is too small or too large, a small sliver can be added or subtracted to the sheet cowling. When the fit is correct, apply regular carpenter glue to the bulkheads and slide into place.

CONTROL THROWS
Control travel for the elevators is 7/8" up and down. For the rudder it is 2 ½" each way. The ailerons should travel 1 1/2" up, and no more than 3/4" down. Importance must be given to this amount of differential in the ailerons, and it will be achieved if the control arm on the aileron servo is made as shown.

At the start of the take off run in a flying boat, one of the tip floats will be in the water. It is necessary to lift this float out of the water using ailerons, or the model will want to turn in the direction of the float that is dragging in the water. Poor aileron design aggravates this problem in many models because of the adverse yaw that is inherent at larger angles of attack, such as while getting on the step. The down going aileron produces more drag than it does lift and turns the model in the wrong direction.

Two things are done in the design of the Solent to overcome this problem. Frise ailerons are used, and a substantial amount of differential is used in the aileron linkage. The position of the aileron horns affects the amount of differential. Placing them too far forward reduces differential. Putting them further back increases it.

At the start of the take off run, while holding "up" elevator to get on the step, advance the throttle just a small amount at first until the wings are leveled with both tip floats out of the water. When this is under control, advance the throttle further and relax on the "up" elevator as the model gets on the step and accelerates. With practice this becomes one smooth continuous movement.

A very slight amount of up elevator may be necessary at the point of lift off, especially if operating off glassy water. If a flying boat ever swerves while on the step during take off, it is an indication that there is not enough back pressure on the elevator stick, but don't overdo any corrections. Because of the light wing loading, the Solent is like a park flyer and slows up quite fast during the landing flare if no power is used. Landings are more realistic if a small amount of power is left on right through the landing, and even while the model is still planing on the hull.

If the elevator throw is set correctly (very little on the Solent,) but the model tends to balloon in the flare for landing (elevator seems too sensitive) the CG is likely too far back. The motor battery should be moved forward about half and inch. In any landings on water, the model should be slowed gradually by holding off in the flare as long as possible, and the elevator stick should be well back before touch down.

Motors
The Permax 480 7.2 volt motors used in the prototype are available in the USA from Tower Hobbies for $9.50 each. These motors are also available in various other forms and usually have the name "FULLY" stamped on the back.. The no load speed is 17,000 RPM. These motors work fine for the 4.1:1 gear ratio specified, and 10x7 four blade props. These props are regular Master Airscrew black nylon 10x7 two blade props that are notched at the centre and bolted together. Probably the performance would be better with two blade APC electric props, but these four blade combinations look scale and performance is adequate. The spinners are the cheap line (very light) handled by Hobby Lobby for two blade props. It is a simple matter to cut slots for the extra blades. There is a Jamara Pro 480 motor available that has a no load speed of 17,000 RPM and this could possibly be used, but has not been tried. I have used the very hot Jamara Pro 480 HS BB motors in other models and they are excellent. However the no load speed is 22,000 RPM. Higher ratio gearboxes or smaller props would have to used. Smaller props would not be as efficient or look as good as the large four blade props. The same would be said to the use of any brushless motors which would require smaller props.

In multi motor electric models, there is an increased 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 when 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. 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. Before using a speed control with BEC, think of the effect it has on taxiing back to shore at the end of the flight if the battery is running low. Without BEC, if the battery is running low before landing, the motors will usually still run sufficiently to taxi back to shore. With a BEC however, the motor 'cut off' takes over, and it is necessary to call for the rescue crew.

COVERING AND FINISHING

Most of the airframe on the prototype is covered with low temperature film. Avoid the use of fabric type (….tex) coverings. They are heavy, and the strong shrinkage could warp the light weight construction. Film covering does not stand up to repeated use in water, so the hull and tip floats are best covered with light tissue (silkspan) applied with nitrate dope. This should be done before covering the upper part of the fuselage with regular film. The silkspan should be applied to the entire hull, and up to the top edge of the sheeting on the sides, this point being a few inches above the water line. Be sure to prime the hull and tip floats by applying two coats of clear nitrate dope before covering.

When applying the tissue, first spray the silkspan lightly with water and rub it on to the surface while damp. Next brush a coat of dope on to the silkspan. It will bleed through the tissue and cement itself to the primed surface below. After it has dried, apply at least one more coat of clear dope. The hull should be sanded after each coat of dope is applied, and when a smooth surface has been obtained, the colour should be applied. Krylon spray paint is known to be one of the lightest and most suitable for models of this type. When painting is completed, cover the remaining section of the fuselage. Allow about an inch overlap where the film joins the top edge of sheeting on the lower part of the fuselage sides. The film covering should not be continued to a point below the water line.

EMERGENCY FLOTATION

With an electric powered model, because of the weight of the batteries and motors, there is not enough flotation to keep the plane on the surface of the water in the event of a crash, or the hull being punctured. Hence it is recommended that blocks of foam be placed in the fuselage, or even some of the wing bays. The small air sacks that are often used as packing are another option. When asked why the model of the Solent is so light, I point out the air bags and say that they are filled with helium. In the case of several multi motor flying boats that I have flown for several years now, I have fortunately never had to put these flotation devices to the test. But in earlier years I lost a small single pylon flying boat following a crash due to radio failure. When I got to the crash scene, all that was floating was the wing and tail section that had torn lose. The weight of the battery and motor had taken the fuselage to the bottom of the lake complete with radio gear and ESC. Had it been a multi motor flying boat, the wing would have probably gone down as well because of the weight of the motors. Flotation is like insurance. You will only need it if you don't have it. For further details on flying boats, read the page about "Flying Boat Design' on Ivan's web page, www.ivansplans.com.

Enjoy building and flying your Solent

Ivan Pettigrew

SOLENT 480 Summary
May 2006. Scale 1/14.5 Span 99 inches. Wing area 1,200 sq. in. Length 73.5 in. Airfoil Selig 7055 with NACA cuff on outboard sections. Weight with ten 3,300 NiMH cells is 124 ounces for a wing loading of 14.9 oz/sq.ft. Four Permax 480 can motors are wired parallel. MP-Jet 4.1:1 gearboxes drive 10x7 four blade props 4,600 RPM. Static current is 38 amps (9.5 amps each motor). Static Thrust: 60 ounces.

July 10, 2006 Update
It seems that Tower Hobbies no longer stocks the Permax 480 motors. At present I do not know of any other source, but I believe the Long Can Speed 400 motor stocked by Hobby Lobby is identical. The only difference is the price at $15.90. The Jamara 480 HS BB motor available in the UK and Europe has the same size case and shaft diameter. It is considered more powerful than the Permax 480, but it has a high speed winding. If using this motor it would be necessary to run a higher ratio reduction in order to use the same four blade prop combinations. The Jamara with the 4.1 ratio gearbox would give good efficiency on regular two blade 10x7 APC-E props., but they would not look so authentic.

July 2007
This season I have used Li-Po batteries. With a 3 series pack the motors draw 33 amps and this is actually quite adequate for power, but even with the pack right up in the nose, there is not enough ballast to bring the C of G up to where it should be. I have gone to putting two 3S 2800mAh packs parallel, thus having enough ballast and having enough flight time for a days flying. It makes it easier on the batteries when there are two packs parallel. They are just discharging at half the rate. At this power, the input to each motor is only 83 watts, less than half of the 170 watts that these motors are claimed to handle. So it makes for long motor life. A speed 400 motor would handle that much power.

If you want some excitement, fly the Solent 480 with a pair of 4 series Li-Poly packs in parallel. The motors will handle it quite OK, and you will think you have the performance of a pattern plane. See the video listed below. Max power static will draw 50 amps, but this will come down to 45 amps when the props unload in the air. With the additional voltage as well as the increase in amps, the power is about double what it is with 3S batteries.

Video with sound: http://www.youtube.com/watch?v=ZNeeWK86GIc

May 2008
With difficulty in finding a reliable ESC to handle the amperage of all the motors wired parallel, the wiring has been change to series parallel. The motors on each side are wired

parallel with each other, and the pair on the port side are in series with the starboard pair. Power is from a 6S pack of LiPos. The voltage is double, but only half of it goes to each motor. The amperage from the battery at 21 amps is now about half of what it was formerly, but each motor is only drawing half of this, 10.5A. The pleasant surprise in this configuration has been the increased efficiency overall. The prop speed is now 5,100 RPM giving 75 ounces of static thrust. For enhanced performance, the model may be powered with 7S LiPos, but check the voltage limit on the ESC. Also check the BEC limit. The BEC in most speed controls is suitable for 3S operation such as used with all the motors parallel, but with 6S operation, it is usually necessary to disconnect the BEC and use a separate receiver battery.