S-51 Final Assembly

Last revised 8/3/00

Introduction

If you have constructed your aircraft as outlined in this manual, you have done about as much as you can in your garage. The principal focus of this section is therefore on those tasks that cannot normally be performed in a standard two car garage. A few of them have been described previously, specifically mating the wing halves. This section includes suggestions for mating the wings to the fuselage, and installing and rigging the flight controls, engine and propeller, and the gear uplocks. It also includes further descriptions of some of the systems installations, specifically the fuel, hydraulic, electrical systems.

Completing the fuel system installation in the wing

At this stage you should already have the finger strainers, flanges and fuel level senders installed in the tanks. If you are installing auxiliary tanks you will also need transfer pumps or, for a gravity flow system, valves. The tanks must be vented appropriately, either as shown in the plans or via the wingtips. You will need to install a fuel selector valve, an auxiliary electric fuel pump, a filter and possibly some additional equipment. In the selection and installation of components, keep the following points in mind.

- An electric fuel pump is required to back up the mechanical pump driven off the engine. Be advised that Airflow Performance strongly discourages installation of the auxiliary fuel pump forward of the firewall.
- If you use an Airflow Performance injection system, the fuel pressure at the throttle body should be between 15 and 40 psi. If you exceed 40 psi you may blow seals in the throttle body. If your auxiliary or primary pump can operate in a manner so as to exceed 40 psi, you will need to install a pressure regulator.
- The approximately 500-600 hp engines typically installed in S51's require at least 0.50" (-8) tubing between the tanks and the throttle body. If you expect to use a higher output engine it would probably be a good idea to go with 0.625" (-10) tubing.
- The fuel return line will need to be at least 0.375 (-6) tubing. If you install a pressure regulator with a purge port, you should combine the purge flow with the return flow and send it back to the tanks. In this case the return line should be the same size as the feed line. To reduce the possibility of vapor lock, *the return line should go to the tanks, not to the feed line upstream of the pumps.*
- The fuel selector valve should be sized to correspond to the feed and return tube sizes. You want one with -8 or -10 AN fittings on the feed side. Ideally the valve will route the return fuel to the tank from which it was taken.
- A fuel filter is required and should be placed upstream of the auxiliary pump. With an Airflow Performance system you do not need to trap particles smaller than 60 microns. The filtering element should be metal; *paper elements should not to be used.*

- You will need to install checkvalves to route fuel around any positive displacement type pump. Most electric pumps are of this type. Most aviation pumps used on larger engines and most sprint car mechanical pumps are not positive displacement.

- Ideally all of the above components should be installed where they can be accessed easily for maintenance. On the prototype everything is installed inside the wing in the center bays. This results in a fairly simple and clean installation, but as mentioned previously one that can be difficult to maintain once the aircraft is assembled. It would greatly increase the ease of maintenance if the fuel filter (at least) could be mounted in a more accessible location. Unfortunately moving the filter effectively requires moving everything but the selector valve, so considerable room is required. Possible alternative locations are in the wheelwells or on the firewall. As mentioned previously, Airflow Performance frowns on the firewall option. As illustrated in Figure 3.1, there is actually a surprising amount of room in the wheelwells.

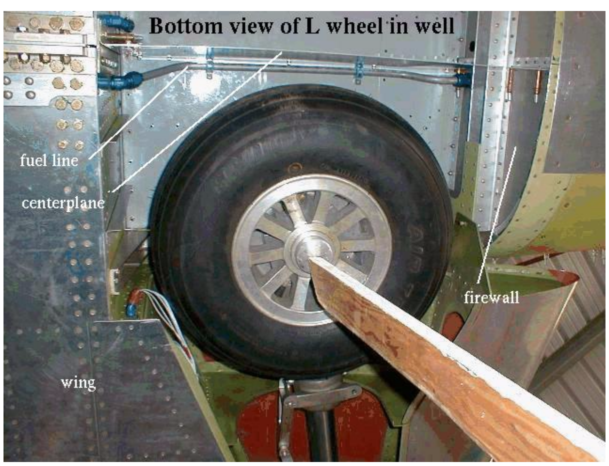

Figure 3.1. The right wheelwell viewed from the bottom.

As a guide, a schematic of a well designed fuel system is shown in Figure 3.2.

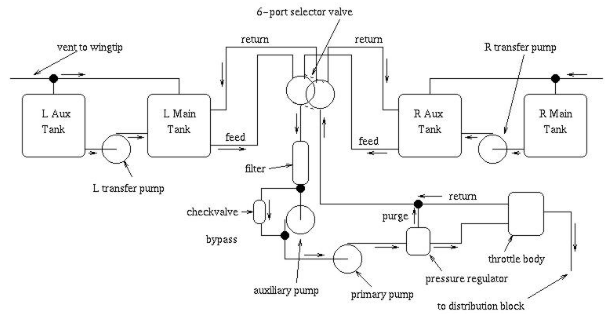

Figure 3.2. Fuel system schematic. This one uses a purge style fuel pressure regulator downstream of the mechanical fuel pump. The purge line is combined with the return line from the throttle body and returned to the tanks through the selector valve.

Builders that purchase kits from PAE will be provided with fuel system components compatible with the PAE engine. Those that bought kits without the engine should read on.

If you are not using a monster engine, certainly the easiest way to obtain satisfactory fuel system components is to buy the entire system from Airflow Performance. They use two Walbro automotive electric pumps in parallel to provide adequate flowrate. These pumps put out maximum pressures below 40 psi, so no regulator is provided (however one may still be needed if your engine driven pump can exceed 40 psi). A checkvalve bypass and filter is included with the system. The selector valve is not included.

Most builders are using a 6-port Andair selector valve. These are not yet available in the required size through the usual supply houses, but can be obtained through Rod Bower (5150 Drive Systems), or directly from the manufacturer.

For builders who want to design their own system, here is some information that will probably be useful.

- Walbro [(248) 377-1800] is a major supplier to the automobile manufacturers, particularly Chrysler Corp. You can probably obtain any of their pumps locally if you know what to ask for. I used Walbro pumps for transferring fuel between the aux and main tanks, and found the technical support people quite helpful in identifying an appropriate pump. However, it would probably be a bad idea to tell them what you intend to put it in!

- Automotive racing suppliers sell a number of electric fuel pumps that will work. Some of the newer ones come with intergal bypass and pressure regulators which, depending on your engine driven pump, may save a lot of plumbing.

- A few builders use a modified Lanceair IV fuel selector valve. These are nice valves and are considerably less expensive than the Andair, however to get adequate flowrates it is necessary to port the valve body and plug. This is not all that simple. Also, Lanceair will not sell them for use on other aircraft, so you either have to convince them it's not going on an aircraft or get a IV builder to order one for you.

- Flapper style checkvalves with AN-8 or -10 fittings are widely available from automotive racing supply houses, for example TMR (714) 771-1348.

The first thing to decide is whether you are willing to put the auxiliary pump on the firewall or in the wheelwell. If you put everything on the firewall, *be sure to protect it from heat.* If you decide to put everything in the wing, as in the prototype, it will make routine maintenance less burdensome if you arrange the plumbing so that the fuel filter is directly below the inboard half of the access port in the top of the right wing. You can gain access to this port without removing the front seat frame, however you will have to remove the seat pan and may have to loosen the section of the cockpit floor which lies between the side of the seat frame and the lower longeron. This floor section should be installed on the lower longeron with screws, not rivets. (Actually, all sections of the floor should be installed with screws!)

In locating components in the wing, keep in mind that you will need to be able to remove and replace all the necessary plumbing through the access ports in the top of the wings. You also need to be able to reach the nuts for the bolts that pass through the upper and lower step fittings, and those that pass through the fitting that joins the front shear webs. The usual procedure is to pass the feed and return lines through the front spar shear web with bulkhead fittings, then run the lines along the fuselage centerplane and just under the cockpit floor to the firewall. Typically builders run the feed on one side of the plate separating the wheelwells, and the return on the other. Ideally the bulkhead fittings should be placed in the center of the shear web (because the stresses are lowest there). If you move off the center, it's better to go higher since the upper section is in compression under positive G loads.

The puumbing is most easily installed in the wings before they are bolted together. After you mate the wing halves, put the assembly on the wing stands, and complete the plumbing, put some gas in each tank and test all the pumps and plumbing for leaks and function.

Mating the wings to the fuselage

Begin by removing the flaps and bolting the wing halves together. You can install all the bolts in the mating flanges except those that go through the right side of the fitting that joins the front spar shear web (3020-12) and those that secure the aileron bellcrank pedestal (8047-2) to the rear spar shear web. An anglebracket (5210-21) which secures aft edge of the plate separating the wheelwells (5210-3) is attached to 3020-12. You will find that the mating process is more easily accomplished without the aileron bellcrank pedestal attached to the spar and without the inner aileron push-pull tubes (8047-6) mounted.

Before you try to mate the wings and fuselage you should check the trimming of the upper wings skins in a couple of places. First you should trim away any skin that extends beyond the aft edge of the upper rear wing mate fitting (3020-7). Also the upper skins should be trimmed straight forward from the root end of the flaps and close enough to the rear spar so that the skin clears the rear wing attach fittings (3020-25).

The mating procedure is best accomplised with the wings supported on the wing stands (Figure 3.3).

Figure 3.3. The airframe mounted on the wingstands. If you join the stands together with angle iron and add heavy duty casters, you can roll the wings under the fuselage.

Jim has a drawing for these stands. As illustrated in Figure 3.4, support the fuselage by two chain hoists from an overhead beam, just about like they did it at the Northrop factories.

Figure 3.4. The fuselage suspended from chain hoists. Note the cement filled tailstand. With the engine installed and the airframe supported in a level attitude at the jackpoints on the wings, the aircraft will be nose heavy.

We recommend this procedure because it makes it relatively easy to position the assemblies accurately. Begin by hoisting the fuselage. The best places to hoist from are the engine mount and a bar passing through the lift tube. You should use two independent straps on either the front or back (or both), and adjust them so that the symmetry plane of the fuselage is vertical.

Wing spars usually come with a couple of 1/8" pilot holes drilled for each of the forward and rear attach fittings (3020-24/25). Use these to cleco the lower attach fittings to the wing spars. There will be some slop in this because the lower fittings are pilot drilled to 3/16". Move the wing under the fuselage and lower the fuselage until the upper and lower attach fittings just touch. Make sure the fuselage is square with the wings by measuring from each wing tip to the fuselage symmetry plane at the tail.

Next, level the wing. The easiest way to do this is with a water level. A water level is just a long piece of transparent wall tubing with the ends attached to each wingtip and filled with water. Adjust the wings so that the water level is at the same point on each tip.

The last step is to set the angle of incidence to $+1°$. First determine the pitch angle of the wing as it sits on the stands. The easiest way of doing this is to measure the angle of the wing datum line at the tip with respect to the horizontal using a Smartlevel. The datum at the root will lie above this by the washout angle, typically $1.5°$. You want to adjust the chain hoists to set the pitch angle of the fuselage to $1°$ below the wing root datum. This is most easily done by taking measurements off the upper longeron back by the tail. You may need to install shims between the upper and lower rear attach fittings to get the incidence angle correct or, if your spars are not pilot drilled, you may be able to get the correct angle by moving the fittings up or down on the spar.

Once you have the geometry set and checked you can locate the attach bolt holes in the lower fittings (3020-24/25) using a transfer punch through the 1/4" pilot holes in the top fittings. Remove the lower fittings and check to see if the hole locations are reasonably close to the center of the fitting. If the distances between centers of the upper fittings is correct, they should be close enough to comfortably install an AN6 nut in the fitting interior. If they are, drill the lower fittings for 1/4" pilot bolts and install them back on the wing. Mate the wings and fuselage as before (with the fuselage mainly supported by the chain hoists) and install pilot bolts between the upper and lower fittings. You can then check the pilot holes in the front spar to see if they line up well with the pilot holes in the lower attach fittings. Adjust the chain hoists as necessary to get the holes to line up as best you can, then recheck to make sure the wings are square with the fuselage and the angle of incidence is OK. If the geometry is correct, the distance between the lower longeron and the top wing skin should be about 0.75" at the closest point. Pilot drill the front spar to 3/16" through the pilot holes in the lower fittings. Unfortunately you will not be able to drill the rear spar in a similar manner. The best you can do is to precisely mark the lower fitting location on the spar.

You can now take everything apart and drill and ream the lower attach fittings and the spar shear web for the AN4 attach bolts. *Make sure the rear fittings do not move during the dissembly process.* Remove the lower fittings and drill and ream both the upper and lower fittings for the AN6 thrubolts. It will work better to take them off and do the reaming on a drill press. Jim recommends attaching the strakes to the firewall with AN6 bolts. Use only a single bolt on each side. You will find the the 21.5" center-to-center dimension in drawing 5300 does not provide adequate edge clearance for AN6 bolts. Just put the bolts near the center of the overlap.

All that's left is to reassemble everything and permanently install the fasteners. The only problem will be getting the nuts on the aft thrubolts. If you have very small hands you may be able to reach the ends of the bolts from the bottom. If not you can install the nuts from the bottom on the end of a long socket extension, but it will probably take you several tries.

When you mount the wings permanently, you should have the center aileron bellcrank (8047-2/3) and inner push-pull tubes (8047-6) installed. In this case you will not be able to insert the bolt or nut from the bottom with your hand. You can use a magnet fastened to the end of rod to hold the bolt, which is inserted from the bottom. This works pretty well.

Installing the main landing gear

If you ahve not already installed the main landing gear, do so now. The general procedure is described in the wing kit writeup. The objectives are the same, but the procedure will have to be modified a bit to account for the wings being horizontal instead of vertical. With the wings mated, the required measurements are actually more direct. Just get the wheels centered in the wheelwells, the strut swept forward 10° and the toe-in at zero.

Before you put any severe sideloads on the main gear you must make arrangements to support the bottom of the rib at WS 43.25. If you do not do this you are likely to bend the rib, knocking your carefully aligned downlock hardware out of whack. One way to do this is to install the cover plates on the bottom of the wings, however this obviously prevents access to the actuators and downlock assemblies. Jim recommends fabricating a couple of new covers (Figure 3.5) from 0.125" aluminum plate, then cutting out the centers of each bay 0.5" or so inboard of the screws. This is apparently sufficient to secure the rib bottom, at least for purposes of testing on the stands and moving about the hangar. It may or may not be strong enough to taxi the aircraft. It would probably be wise to play it safe and install the original covers before you taxi.

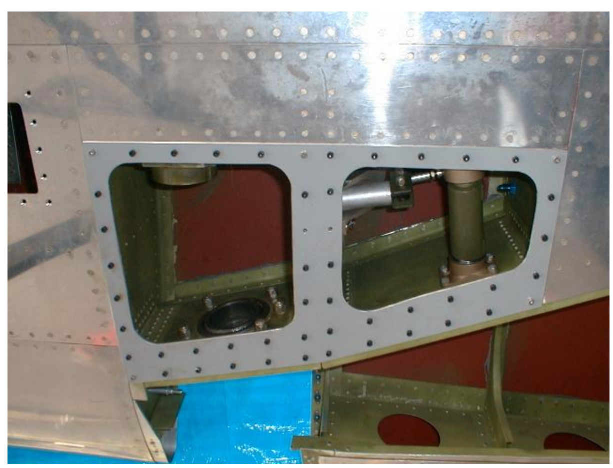

Figure 3.5. Cutout plates hold the center rib in position.

Installing the main gear actuators

The upper rear quadrant of the actuator cutout in the rib at WS 43.25 typically needs to be enlarged in order to get the actuator barrel to fit with the gear in the up position. The actuator barrels currently furnished have the holes for the hydraulic fittings on the same side. However, drawing 7020 shows the fittings on opposite sides. The reason for this is that if the AN fitting at the outboard side (the upside of the actuator) is mounted below the actuator, the other AN fitting will come very close to interfering with the downlock idler arm (7020-4) in the initial part of the transition from gear down to up. Depending on your idler arm geometry and how you welded in the added web on the arm attached to the actuator, it may very well hit. If you have this problem, the easiest solution is to drill a hole in the opposite side of one end of the actuator barrel, then orient the fittings as in 7020. To get the actuator installed in the idler arm, you will have to trim away some of the web in the arm. The problem is that there is insufficient clearance to get the bolt installed. You will also encounter this annoying problem in rigging some of the elevator push-pull tubes.

The downlock microswitches

You will need to install a DPDT microswitch on the main gear downlock levers (7020-3). They should be installed in such a manner that the contact will be made when the downlock lever lug is seated against the stop and the downlock pin is *fully engaged*. The usual method of attachment and adjustment is via a plate (see Figure A.16) bolted to the downlock lever. Be sure to keep the bolt holes clear of the lug itself, as show in Figure A.16. On some of the gear the lug apparently extends farther into the lever than indicated in Figure A.16, so we suggest placing the second bolt well back towards the trunion. A good installation is illustrated in Figure 3.6.

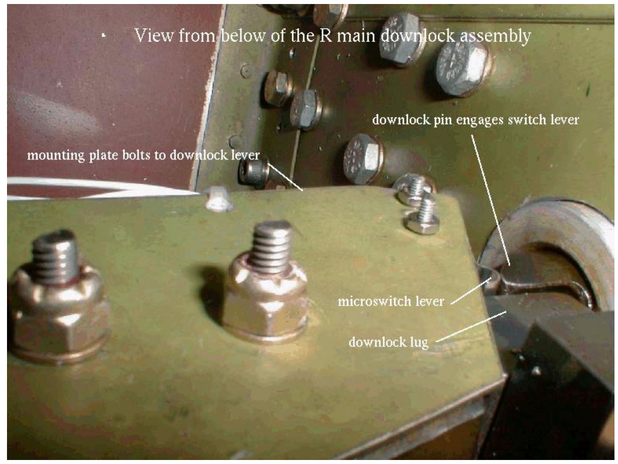

Figure 3.6. The downlock microswitch installon on the R main downlock lever. Note the full engagement of the pin with the lug. The microswitch should be adjusted to activate only when the pin is fully engaged.

Hydraulic Plumbing

The following outline applys if you use the spool valve provided with the kit and mount the hydraulic powerpack in the place provided on the rear seat frame. For installation of the spool valve provided with the kit, see Figure A.18.

Many builders are using different spool valves adapted from industrial equipment which have much lower internal leakage rates than those provided with the kit. There is some merit in this, since it will keep the powerpack motor from cycling periodically with the gear in the down and locked position. Uplocks are required on all the landing gear, so there is no real need to keep pressure on the actuators with the gear in the up and locked position. Just wire the powerpack relay coil through the uplock switches so that the power can be applied only when the gear not up and locked.

It might be tempting to omit the uplocks and hold the gear up with hydraulics. This is not a good idea with the S51 because the main gear geometry results in very large forces on the actuators when the gear is in the up position. This (and the lack of an up-and-locked cockpit indicator) caused a lot difficulty with the prototype. Performance of positive G aerobatics with the uplocks not engaged actually resulted in bent actuator shafts and a couple of expensive gear up landings. The current actuators have larger (0.875") shafts, but you can see it is possible to put a great load on them. So do install the uplocks, and make sure you can confirm that they are engaged before you pull significantly more than one G.

Figure 3.7. Hydraulic lines installed in the airframe. This example uses the spool valve supplied with the kit. The lines aer supported by brackets attached to the top of the duct and the bottom of the fron seat frame. The high pressure oxygen line is for a oxygen system installed in the tailcone.

As supplied from the factory, the hydraulic pump runs only in one direction. A check valve is installed internally so that no pressure differential can be supported in the opposite direction. This allows the gear to free fall when the uplocks are released, even without power to the pump. Some builders have replaced the checkvalve wich a plug so that the pump can operate in a reversible manner. Jim does not recommend this. It does allow you to omit the spool valve, but a dump valve will have to be installed for emergency use and an additional pressure switch will be required. We have not examined how this modification might effect the eventual installation of the inner gear doors and associated actuators and sequencing valves, but we imagine it will. An example of the hydraulic pumbing is shown in Figure 3.7. Quarter inch 5052 aluminum tubing should be used for all the hydraulic lines. Softer alloys may fail under pressure. The pressurized line is on the inboard side of the pump as it is mounted on the seat frame.

A pressure switch is installed in this line and wired into the pump relay coil so as to disable the pump when the pressure exceeds 1500 psi. See the example in Figure 3.8. The hydraulic pump can draw up to 50 A, so a relay is required. Most builders use the same part used for the master relay. The blue wire on the powerpack should be connected to +12 through the relay, and the black to ground. The green wire is not used (unless you want to run the pump in reverse).

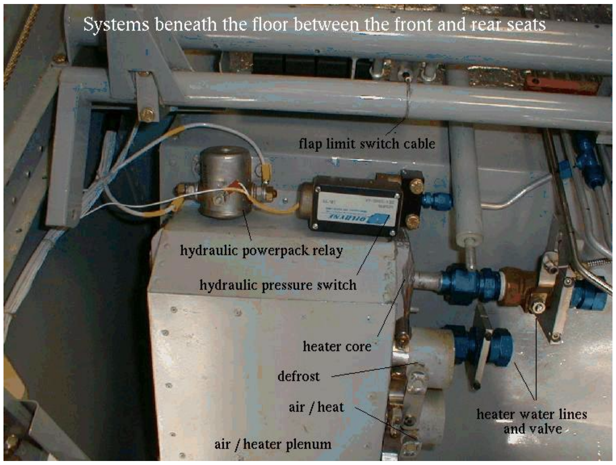

Figure 3.8. The hydraulic powerpack realy are pressure switch. This installation includes an automotive style cabin heating system.

Flap relays and limit switches

Since the flap screwjack does not incorporate limit switches, they must be installed by the builder. Most arrangements we have seen use a limit switch on one of the outboard arms of the torque tube to sense one limit, and one on the common arm driven by the the screwjack to sense the other. This should work OK if you build enclosures for all of the apparatus, as many builders are doing. In the interests keeping the interior work to a minimum, some builders try to avoid building enclosures if at all possible. In this case the arrangement shown in Figure 3.9, which puts the limit switches under the rear seat pan, is recommended. The above example uses a 1/16" cable wrapped around the flap torque tube, running under the seat and secured at the rear with a spring. A slug is clamped to the cable with a setscrew, and moves back and forth in a channel as the cable winds and unwinds on the torque tube. The limit switches are mounted in the channel and are activated when the slug passes over them. The only drawback to this arrangement is the relatively short travel of the slug; about 0.5 inch. This makes the limit settings very sensitive to any movement of the switches relative to the rear seat frame (to which the torque tube is secured). To overcome this problem, the slug channel is machined into a bracket which is glued and riveted to the seat frame, and the limit switches mounted on this.

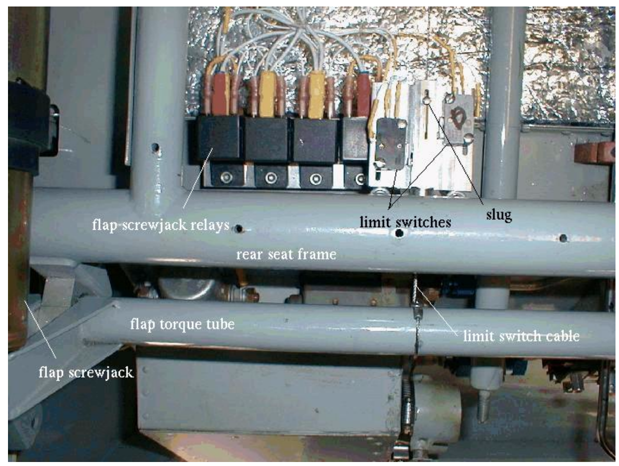

Figure 3.9. Here the flap limit swtiches are actuated by a slug moving back and forth on a cable. The SPDT relays are common Bosch headlight relays rated at 40A. Four realys are wired in a DPDT arrangement.

The flap screwjack can draw a bit less than 20 A, so most builders use a 20 A breaker. This is too much current to switch with an ordinary toggle switch, so once again a relay is required. Ideally, you would like a DPDT relay, which can easily be wired to reverse the polarity to the screwjack. However, it's difficult to find compact DPDT relays which will handle 20 A. Most builders use 4 SPDT relays instead. Bosch makes some 40 A SPDT relays that should be readily available at your local import car parts store. The characteristics of the various part numbers are available online at http://www.bpg-inc.com/bosch/index.htm. Many builders use the 0-332-209-150 mini-relays wired as shown in Figure 3.10.

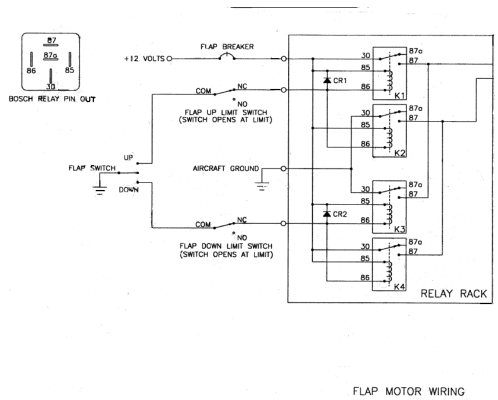

Figure 3.10. Schematic illustrating how 4 SPDT relays can be wired so as to repalce a DPDT relay. 1N4002 diodes will work for CR1 and CR2.

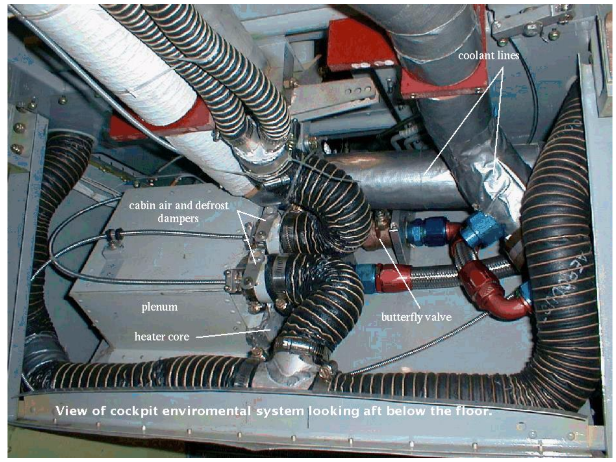

Figure 3.11. A hot water based cabin heat system.

Cockpit environmental controls

Some builders install a cabin heat system. Most of them take low pressure hot air from behind the radiator and mix it with higher pressure cold air from in front of the radiator using a damper. Alternatively, you can install an automotive heater system using an GM aluminum heater core. In the latter, hot coolant is taken from upstream of the restrictor plate (or, if you do not run a restrictor plate, upstream of the radiator). The coolant flow through the heater core is controlled with a butterfly valve which is opened and closed from the cockpit via a push-pull cable. The coolant is returned downstream of the restrictor plate or radiator, as appropriate. Cabin air is taken from in front of the radiator and routed through the heater core, so that the amount of heating is controlled by the butterfly valve. The air exits the heater core into a plenum which feeds both the eyeball vents and defrost vents through dampers. Figure 3.11 shows the completed assembly.

Builders typically fabricate cabin air ducts from sheet aluminum and rivet them to interior of the fuselage skin. Alternatively, you can construct the ducts from 2" 0.049 wall 6061T6 tubing (Figure 3.12). In order to avoid interfering with the rudder cables and having the duct protrude into the cockpit, the tubing is squashed into an elliptic cross-section, with the minor axis slightly less then 1.5". In the arrangement pictured in Figure 3.12, the duct comes through the floor just behind the rear wing attach fitting, up to just above the upper longeron, then fore and aft to eyeball vents. In order not to obstruct the flow where the duct passes over (or through) the upper longeron, it will be necessary to trim away most of the longeron web. The structure removed is replaced by doublers made from 0.125" 6061T6 plate, welded to the duct and screwed to the longeron upper and lower web. *This makes this section of the duct part of the aircraft structure, so it should be built to structural standards.* The duct is connected to the eyeball vent plenums via squashed 2" SCAT tubing, and everything above the upper longeron is concealed beneath panelling made from 0.025" aluminum sheet. To use this arrangement you will need to make some low profile aluminum flanges (Figure 3.13) that adapt the eyeball vent to the SCAT tubing.

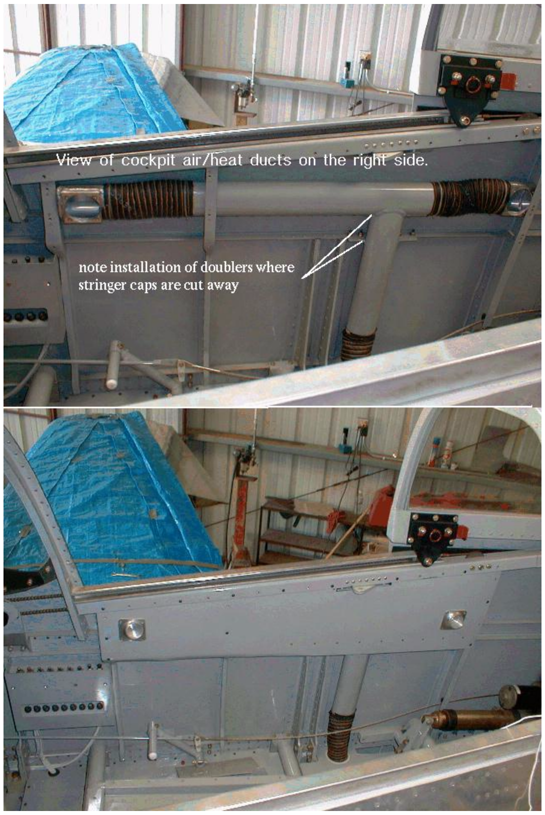

Figure 3.12. An example of a duct constructed from tubing.

Figure 3.13. Low profile flanges to mount the eyeball vents.

As illustarted in Figure 3.14, the top of the console is a good place to put the controls for the heater valve and cabin air and defrost air dampers. Unless you intend to use manual trim, there will be plenty of room.

Figure 3.14. In this example the controls for heat, defrost and air are put in the console.

Installing Dzus fasteners in the cowling

You need to get some special tools for this job; specifically, a set of dimple dies, a spring adjustment tool and possibly a heavy duty squeezer. You can get dies and the spring adjustment tool from Skybolt, however Rod Bower has a set of dimple dies that work a lot better. He had them made up by Cleveland Tool. Clevelend tool is not producing them for sale as the demand is limited and they would necessarily be pretty expensive. If you want to use them, we suggest you talk to Rod. These dies require a squeezer which will exert at last 6000 lbs of force - more than the smaller squeezers can muster.

The first problem is that there will likely be inadequate clearance between the Dzus fastener holes and the edge underlying structure in some places. This is often a problem where the cowl skins mate to the firewall doubler, and where they mate the to doubler installed on the chin scoop. You can extend the firewall doubler about a half inch using 426-3 rivets and structural adhesive. You will probably have inadequate space to install Dzus fasteners in between the forward ribs and the aft edge of the chinscoop. Here we recommend replacing the Dzus fasteners shown in the plans with 1/4-28 flathead screws, as pictured in Figure 3.15.

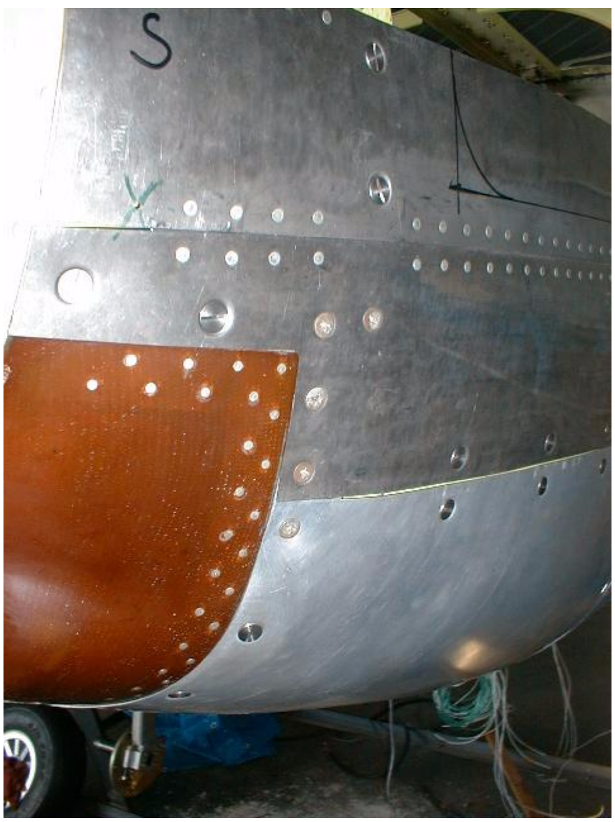

Figure 3.15. There will probably not be enough room to install Dzus fasteners just aft of the chinscoop. There 1/4-28 screws are used instead.

Dimple dies for 1/4" screws can be obtained from US Tool and Supply.

Rod's dimple dies come in 4 sets. Set #1 is used to form the dimple in the skins for the stud. Set #3 is used to deepen the bottom of this dimple to allow room to install the stud locking collars. Set #4 is used to dimple the underlying structure. There is an additional die that is used to crimp the locking collars into place. There are some tricks to using these dies. Rod has a set of written instructions which cover some of these, and we have incorporated his suggestions into the following.

- Ream out the fastener holes to 5/16". If you choose not to do this in place, make sure to use a Unibit to insure that the pilot hole is not moved in this process. *Make sure you completely deburr each hole in the skin.*

- You will need a heavy duty squeezer capable of exerting at least 6000 lbs force to dimple the skins. Use the #1 die set. Even though the dies have pilots, it is not that easy to get the dimple formed exactly concentric with the hole. Here is the procedure we found to work best: Mount the squeezer vertically on the bench with the male die on the bottom. Place the skin with the interior side up on the male die pilot and squeeze just enough of a dimple so that the hole begins to enlarge. Then back off on the squeezer and check to make sure that the gap between the pilot and the hole is uniform around the circumference. If necessary, adjust the angle at which the skin is held until it is, then complete the squeeze.

  Check the dimple depth by inserting a stud and laying a straight edge along the surface. If the dies are adjusted properly and the squeezer exerts enough force, the surface should be perfectly flat. A surface which is "dished in" is evidence of insufficient force or incorrect engagement. There are a few holes that cannot be reached with most squeezers. We put in these dimples using the above procedure with an Avery tool and hammer. Surprisingly, this seemed to work fine.

- Use the #3 dies to deepen the dimple. If you squeeze slowly the skin will center in the dies automatically.

- Install the locking collars using the male #1 die and a flat rivet set. The holes need to be at least 3/8" to accept the locking collars. The #3 die usually does not expand the holes quite to this diameter, so you will likely have to enlarge them with a reamer or Unibit. Insert the locking collar from the bottom of the hole and crimp. The pilot on the #1 male die is long enough so that the collar cannot be fully crimped, hence you can still get the stud in and out easily after this process. *You do not want to lock the studs in until you are sure they are the right length.* Also, if you plan to paint the cowl you may want to so before installing the studs permanently.

- The retaining springs are attached with 426-4 rivets. These holes should be drilled in the underlying structure before the Dzus holes are dimpled. Make a platenut jig with a 5/16" (or 3/8", see below) mandrel and a pair of 1/8" holes located 0.50" on either side. Use this to locate and drill the rivet holes.

- The cowl skeleton is apparently heat treated to a higher degree of hardness than the skins. It is therefore more prone to cracking, especially where it is necessary to dimple through multiple layers. *To avoid cracking, the holes in the underlying structure must be drilled out to 3/8" (using a Unibit) before dimpling and then completely deburred.* The dimples are formed with the #4 dies, which unfortunately have a 5/16" pilot. We found that the material would center OK in the dies if the die halves were brought into contact slowly while wiggling the material slightly. If you had to shim the underlying structure extensively, you may need to use a countersink instead of (or in addition to) dimpling. You can get 100° countersinks in up to 1" diameters from McMaster-Carr.

- We recommend squeezing the dimples for the retaining spring rivets. Where the underlying structure was in several layers due to doublers or shims, you will use a countersink instead. The rivet holes lie close enough to the Dzus dimple so that you will have to bevel the edge of the female -4 dimple die.

- The retaining springs are installed with the small end of the coils against the underside of the substructure. You can install the retaining spring rivets with a gun or squeezer, but in either case you will probably need to make a special bucking set which fits up inside the spring coil. We used a gun and made a buck by grinding an old surplus 3/32 470 rivet set appropriately, then mounting the shank in a block to provide some mass. You will probably find that the rivet heads extend slightly into the Dzus dimple. You can take care of this by touching them with a sanding cylinder in a die grinder.

- Assemble everything and check to see that the stud length is correct. The studs supplied with the kit are on the long side, hence you will usually have to use the spring adjustment tool to increase the distance between the spring body and the substructure. If you have shimmed a great deal, you may find it necessary to use a longer stud, which are available form SKybolt. Keep in mind that when the locking collars are fully crimped the stud will fit slightly looser than it does now.

- The studs are installed permanently by completing the crimp on the locking collars. A female die which will accept the stud is provided for this purpose. Use a flat rivet set on the head of the stud.

Installing gear uplock assembly

Uplock assemblies are installed on both the main gear and tailwheel. These serve two purposes; to reduce wear and tear on the hydraulic powerpack and to eliminate the potential for damage to the main gear actuators by high G loadings. The former is necessary because the spool valve furnished with the kit typically leaks interally, allowing fluid to pass from the high to low pressure side of the actuators. As a result, you can expect the pump to "burp" frequently, whenever the pressure falls below 1500 psi. The hydraulic powerpack relay is typically wired through the uplock microswitches so that it is disabled when the gear is up and locked. The S51 was originally manufactured with 0.375" shafts on the main gear actuators. Due to the poor mechanical advantage of the main gear actuation system in the up position, it was possible to put enough pressure on the actuators to bend the shafts if several positive G's were pulled without the gear being locked. The prototype experienced two gear up landings due to this problem before Jim increased the shaft diameter to 0.75" and installed a cockpit indication of the up and located condition. Needless to say you should be sure to install an up-and-locked indicator, and be sure it is illuminated before you do aerobatics!

Installation of the tailwheel uplock hook is pretty easy. The most difficult part is running the actuation cable from the hook to the spool valve underneath the gear selector console. Be aware that the spool valve shaft moves opposite the direction required for the uplock hook, so you will also need to reverse the direction somehow. As shown in Figure 3.16, this can be done with a bellcrank. Run a cable from the bellcrank back to the hook. Most builders use Bowden cable so as to avoid installing pulleys.

The main gear uplock is a bit more difficult to install because the design does not provide for adequate clearance with the gear itself. Here is what we recommend. The first step is to find the projection of the axle centerline on the bottom of the cockpit floor when the gear is up as far as it will go. The forks should be in contact with the upper wing skin. If they are not, you probably need to cut out the inboard rib as described in the wing assembly notes. Probably the easiest way to locate the axle center is to take a short length of 1.125" rod and turn one end to a point. You can insert this into the axle ID and trim is as necessary so that the point just contacts the floor when the gear is up. Then mark the floor by lightly tapping its upper surface.

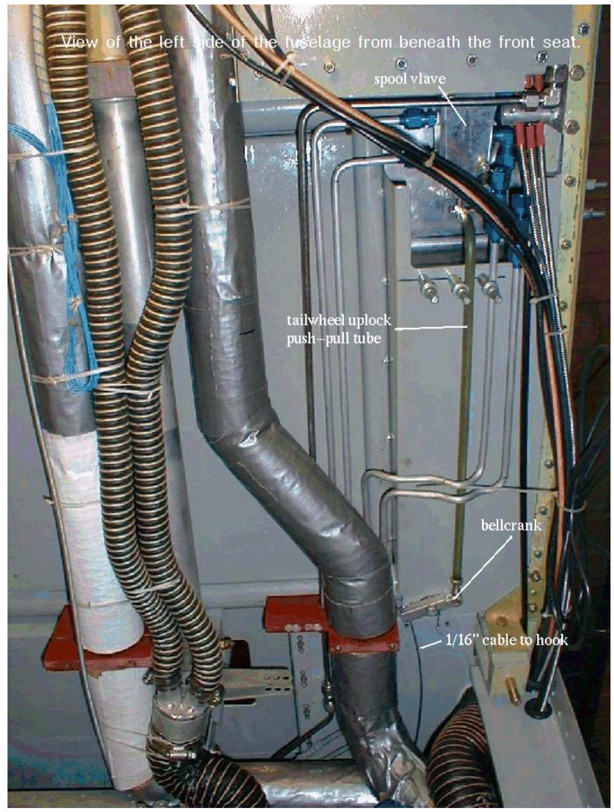

Figure 3.16. The push-pull tube and bellcrank for the tailwheel uplock mounted on the bottom of the front seat frame. This installaion uses 1/16" control cable instead of Bowden cable.

Lay out a line 3.50" forward of the marks. The structure that carries the uplock hook torque tubes (7011-3/4, hereafter referred to as the carry structure) should be centered on this line. Assemble the uplock hook torque tube (7011-5/6) and carry structure and clamp it into place as illustrated in Figure 3.17. Then (with the wheels removed) swing the gear into the up position and prop them up with lengths of wood. If the geometry is correct, *the AN6 bolt and sleeve that engages the uplock hook should be directly below the uplock hook torque tube.* You may have to install shims between the floor and the carry structure in order to get the hook to engage properly. This is highly dependent on exactly how you mated the wings and fuselage.

Note that with the uplocks installed this way there is essentially no clearance between the nut on the AN4 bolt that serves as the axle for the uplock hook torque tube and the fitting (7012-26) that holds the bolt that the hook engages. Similarly, if you rotate the uplock hook forward you will notice that it will barely disengage before it hits the carry structure. According to Jim the solution for this is to notch both the fitting (Figure 3.18) and carry tube (Figure 3.19) until you achieve clearances you are comfortable with. The fitting is no problem, but if you notch the carry tube you should probably install a doubler on the opposite side to restore its strength.

As illustrated in Figure 3.20, you will need to install microswitches on the uplock hooks in such a manner that they are activated when the uplocks are engaged. This circuit must activate a cockpit up-and-locked indicator and also disable the hydraulic powerpack motor. Depending on what microswitch you use, it may be necessary to extend the forward-facing edge of the uplock hook in order to mount the switch.

Once you have the carry structure installed, you can install the idler torque tube (7011-2). There are a couple of versions of this part, and some were apparently produced without all the necessary features (see Figure A.19). In the version illustrated in drawing 7011M, the elements that actuate the inner gear doors are replaced with sections of straight tubing. This will be satisfactory if you do not intend to install inner gear doors. So far, no one has. There are a couple of reasons for this. The first is that no parts have yet been shipped. The second and probably more important is that their installation complicates the system enormously, also increasing the number of potential failure modes. It might not be a bad idea to go without the inner doors for a year or two, until Iyou are sure the basic gear system is satisfactory.

In the installation of the idler torque tube, you will need to make a cut in the left side of the cockpit floor for the lever which connects to the hydraulic spool valve. You may have to shorten the push-pull tube which connects these elements by quite a bit.

Figure 3.17. The uplock carry structure held in place with clamps.

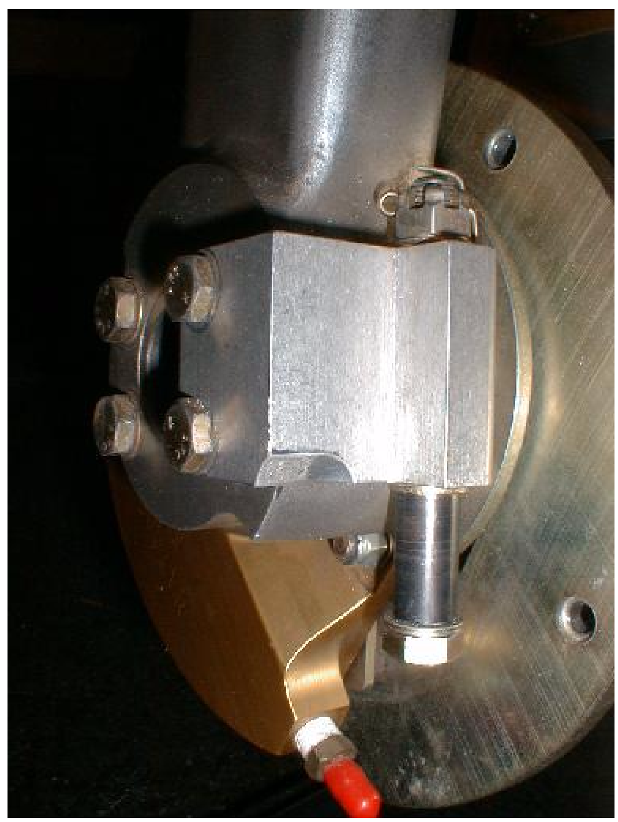

Figure 3.18. You will probably have to trim part 7012-26 to prevent interference with the carry structure.

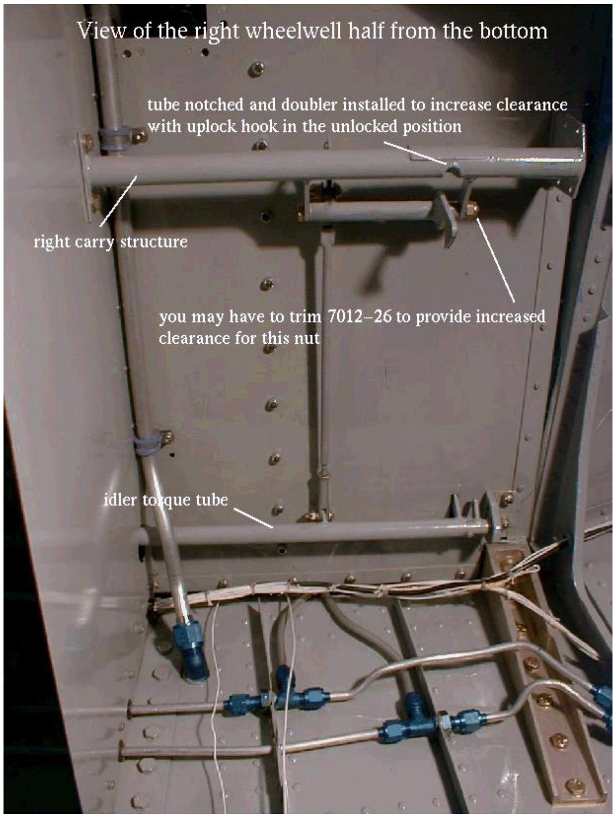

Figure 3.19. You must use some means to increase the disengegement of the gear from the uplock hook. The notch shown is one solution.

When you finish you should adjust the linkages so that pin attached to the fork will hit the aft edge of the uplock hook as the gear comes up, seats fully in the hook when the gear is up, and has adequate movement to disengage reliably. This is most easily done without the wheel mounted. With the wheels mounted you may find that the gear will not go up far enough to engage the uplock hooks. If this is the case, try the following.

- Make sure the uplock hook is not hitting the brake disk. You may have to trim a bit off the bottom of the hook.
- Make sure the voltage at the powerpack relay is about 14 V. When the pressure is fully developed the powerpack will pull at least 50A at this voltage, so make sure your wires are sized accordingly. The easest way to to power the system at 14 V is to connect it to a running vehicle via jumper cables. At 14 V, the powerpack should be capable of pressurizing the system to 2500 psi. According to Jim, 800 psi should be sufficient to get the gear up.
- According to Oildyne (via Jim), the powerpack works better with automatic transmission fluid (Dextrol, type III) instead of the usual MIL spec hydraulic fluid.

Figure 3.20. The main gear uplock microswitches mount on the unlock hooks.

- Make sure you do not have any leaks in the actuators and that the spool valve internal leakage rate is minimized. You must seal the actuator piston to the shaft, either with an o-ring or some sort of synthetic gasket material. You can buy washers with o-rings molded into them from Earl's, and these will work fine.

Installing main gear strut doors

The strut doors on the kit built aircraft are somewhat different than those on the prototype. This may help explain why the parts furnished for this assembly do not seem to fit very well. In addition, the documentation is not very complete. If you are easily frustrated by parts that don't fit and lack of installation drawings, better take a tranquilizer before you start. In fact, better keep the whole bottle handy. There is a drawing of the strut door installation (Figure A.20), but it is of little use.

The best procedure is to begin with the door hinge, the fiberglass stiffener and the linkages that attach the door to the strut. Leave the door itself until later. Assemble the lower half of the hinge and the aluminum brackets to the fiberglass stiffener (as per drawing 7305, except as follows).

- The aft linkage attachment hole needs to be moved down 0.4" on the stiffener in order to get the linkages parallel in the down position.
- The depth of the brackets that accept the linkage mounting bolts needs to be reduced about 0.1".

Use pop-rivets to fasten the side brackets (7305-5/6) to the stiffener. Mount the lower hinge half to the top bracket (7305-7/8) with a single #3 Cleco through one of the pilot holes in the second row from the top. Secure the bottom of the hinge to the bracket with a small C-clamp. Attach the assembly to the strut using the linkages provided. Mate this to the upper hinge half using a length of quarter inch rod about a foot long for the hinge pin. The upper hinge half with the odd dash number goes on the left. Using some rolled paper and/or tape, fit a rod a foot or so long snugly inside the trunion shaft. The purpose of this is to provide a projection of the trunion axis with which that of the hinge axis can be aligned. Then, with the gear in the up and locked position and with the Schrader valve removed, adjust the linkages and hinge position so that

1. the fiberglass stiffener is roughly centered in the strut well
2. the lower surface of the fiberglass stiffener follows the contour of the lower wing skin
3. the wing rib is in contact with the upper hinge half along its length (from top to bottom)
4. the projections of the hinge and trunion axes are roughly parallel.

It helps to have someone to assist you in this. The best way to accomplish item (4) is to sight the projection of the rods from the side to see if they are in a plane (Figure 3.21), then measure the distance between them at two points to see if they are diverging or converging. Before you can satisfy (2), you will have to relieve the forward top corner of the upper hinge half as illustrated in Figure 3.22 in order to get the hinge mounted high enough. In order to satisfy (1) and (4) you will probably have to install about a 0.08-0.10" tapered shim under the forward edge of the upper hinge half. In order to satisfy (2) and (4) it will be necessary to put considerable twist in the fiberglass stiffener. See Figure 3.23. If you examine it carefully, you sill see that some twist is cast into the part. It may be necessary to change the angle at which the lower hinge half is mounted on its bracket. If it is, this can easily be done by loosening the clamp. Once you have everything set, mark the position of the upper hinge on the rib. Also, use a flat sheet of stock to get some idea of how much twist is in the stiffener.

Now lower the gear. You will have to relieve the doubler on the front edge of the strut well to provide clearance for the forward gear door linkage. You can use an AN6-59 bolt to fasten the linkages to the strut, or by making different bushings you can use a smaller diameter, less expensive bolt. With the bolt head oriented forward, There is usually just enough room the get the head to clear the wing skin. The doubler the door lies against (3214-43) often has to be cut away completely in this area. According to Jim, this is normal.

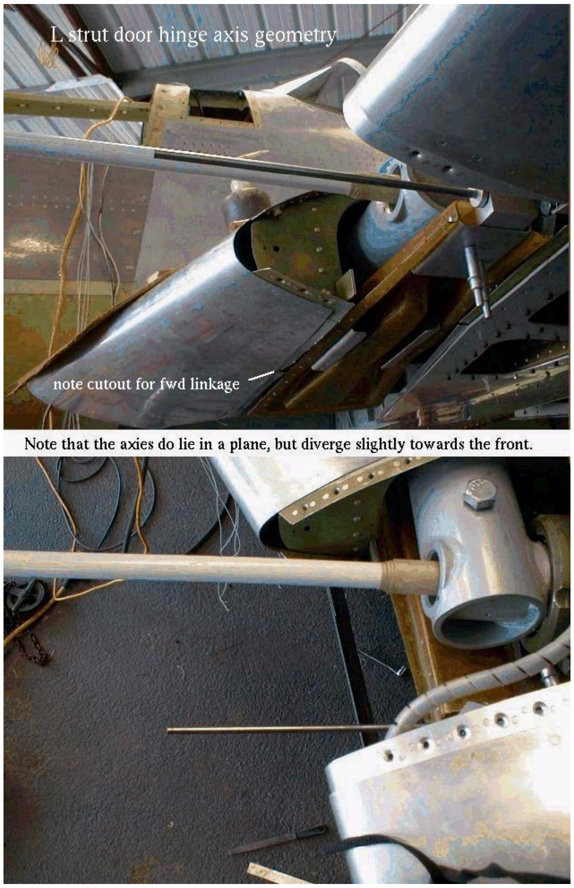

Figure 3.21. The strut door hinge line should be roughly aligned with the trunion axis.

With the gear in the down position, restore the upper hinge half to the marked position. Check the following:

- The hinge and trunion axis should be roughly parallel. We say roughly only because the gear strut is welded to the trunion shaft at a bit more than a 90° angle, about 91.5 to 92° as near as we can tell.

- The strut door linkages should lie in the plane of the tube welded to the strut to which they attach. You can determine this by stepping back, sighting down the tube axis and viewing the linkages from this position.

- The linkages should lie at an angle of a bit more than 90° with respect to the top part of the strut.

- Make sure the twist in the stiffener is about the same as it was in the up position.

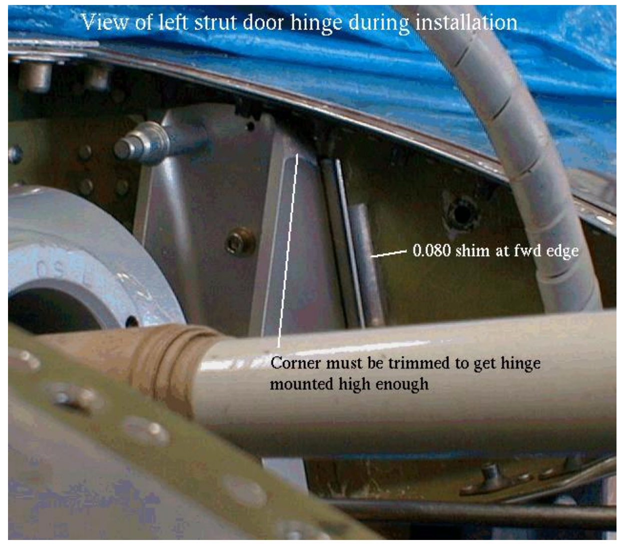

Figure 3.22. The top forward corer of the upper hinge must be trimmed off.

Iterate on whole process (raising and lowering the gear) until you have everything satisfied as best you can, then drill a small hole in the center of the upper hinge half and fasten it to the rib with a small screw or a draw Cleco. Go through the above process again with the upper hinge half fastened in place. Mark the hinge edge and confirm that it is not rotating when the gear is cycled. If everything is OK, you can drill the hinge and rib for a couple of the hinge attach bolts and mount the hinge to the rib with the doubler (3213-10) installed on the outboard side of the rib. The pilot holes drilled for the doubler at the factory are meaningless; ignore them. Check the fit again. If everything is still OK, you can remove the assembly and drill all the pilot holes for the lower hinge half in the top bracket.

The next step is to fit the skin. It is best to use a piece of scrap to make a pattern for the doors. Or you can start with a nice new piece of 0.050” 2024T3, in which case you will probably soon have a nice piece of

0.050" 2024T3 scrap. Drawing 7305 is generally accurate except at the top, where you might as well ignore it. The dimensions in the drawing include about a quarter inch trim allowance along each side.

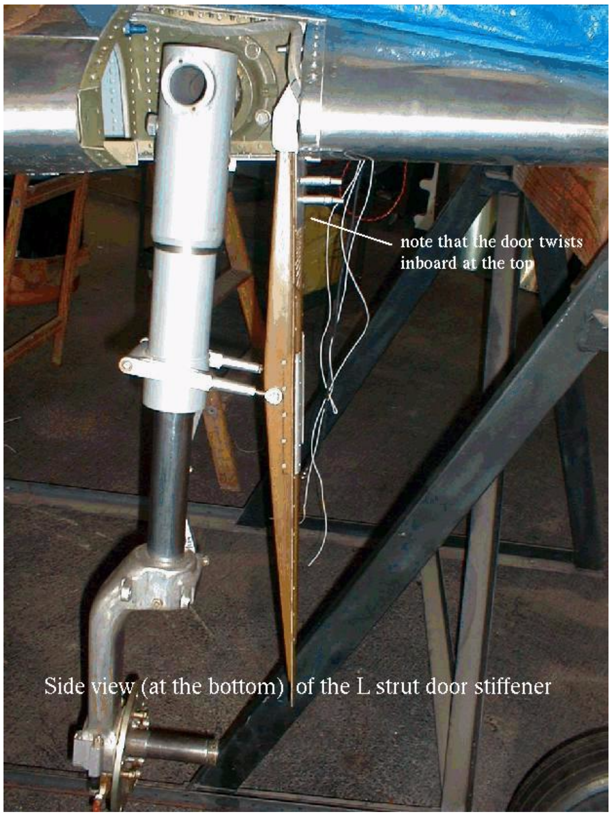

Figure 3.23. Note the pronounced inboard twist in top of the strut door.

To start with, it's probably easiest to cut the top of the pattern even with the top of the lower hinge half. This will result in a great deal of clearance at the outboard edge when the gear is up, but will allow the gear to move up and down with binding at the top (or outboard) side. You need to trim and fit your pattern to the wheelwell, put in the necessary twist, and roll the forward edge so that it fits properly. The top part has to be rolled on a tighter radius than the bottom. Attach the skin to the hinge bracket using a single Cleco and with the gear in the up position, clamp it at the bottom to the fiberglass stiffener. Remove the assembly pilot drill the holes for the rivets in the skin. You can use a strap duplicator to pick up the holes in the hinge bracket.

Trim the door so that it fits the sides of the wheelwell in the up position. After the pattern fits properly along the sides you can figure out what to do with the top or outboard edge. The goal is to get the upper part of the door to extend above the lower skin when the gear is down, and to come flush with the lower skin when the gear is up without binding while it is in transit. To do this you will have to restore part of the skin cut from the underside of the wing at the factory and also extend the door above the hinge line. Interference can be reduced by forming the part above the hinge line inboard a little, so that it lies slightly above the lower skin when the gear is up. Still, you can expect to end up with a little gap. About a quarter inch is typical.

Once your pattern fits, you can use it to form the doors, locate the rivet holes, etc. This is the easy part. Be sure to install the fiberglass stiffeners with both structural adhesive and rivets. To keep the correct twist, first apply the glue and Cleco the stiffener to the skin, then *mount the assembly back on the strut and let the glue cure in place.* If your Schrader valve is oriented outboard, you will have to cut a hole for it in the fiberglass stiffener.

Wingtips, fairings, etc.

Unless you bought your kit from PAE, you will get fairings, wingtips, etc. made from fiberglass. The quality of these parts is very uneven. Jim shipped a lot of flimsy "potato chip" parts, and some of the more sturdy parts have a lot of voids in the gel-coat. For a price these can be replaced by metal parts, either through PAE of directly from the two gentlemen who are currently making them; Mark Kennison (937) 884-5930 or Louis Techinoff (805) 773-1766. If you're interested, you can call them for price and delivery. The only way you can judge how well the parts fit and whether delivery can be expected as promised is to ask for references from previous S51 builders.

The fit of the fiberglass parts is not too bad except for the front part of the tail fairings. You will have to do major surgery on the latter to get it to fit. Probably the only advange of the fiberglass parts is that they can be used to hide an antenna. In particular, an Archer nav antenna can be hidden in the wingtip provided that you extend it about 3 inches.

The best material we have found to fill the voids and pinholes in the gel-coat is Evercoat Finishing Putty. This is a two part material that spreads nicely with a puttyknife or squeege, hardens rapidly and sands easily. You should be able to find it wherever auto body supplies are sold. Use a scribe to roughen up the bottom surface of the larger pits before you fill them.

The smaller tips come in two pieces, separated at the symmetry plane. Mount each of these separately to the flying surface with Clecos, then apply epoxy at the seam and hold the halves together with duct tape. After the glue has set you can remove the tip and lay up several laminatons of fiberglass along the inside surface at the joint. Then you can file and sand the exterior to get the radius you want on the end. The tips can be attached with 6-32 flathead screws and Tinnerman countersunk washers.

The joggle cast into the vertical stabilizer tip should be trimmed away before fitting. You will want to trim the horizontal stabilizer and elevator tips so that the ends lie in a line. The span of these surfaces should decrease towards the rear, so that the line will not be perpendicular to the aircraft's roll axis. This is not critical, so just refer to a picture or use whatever pleases your eye. The wing tips are typically too long. You will probably have to trim and recoutour the aft end. The jog on aft end will have to be trimmed away completly to clear the ailerons. The mold was made from prototype parts, which are different in this respect.