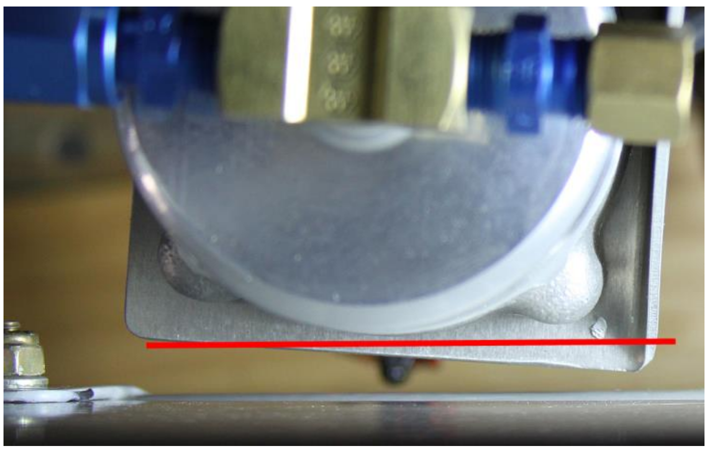
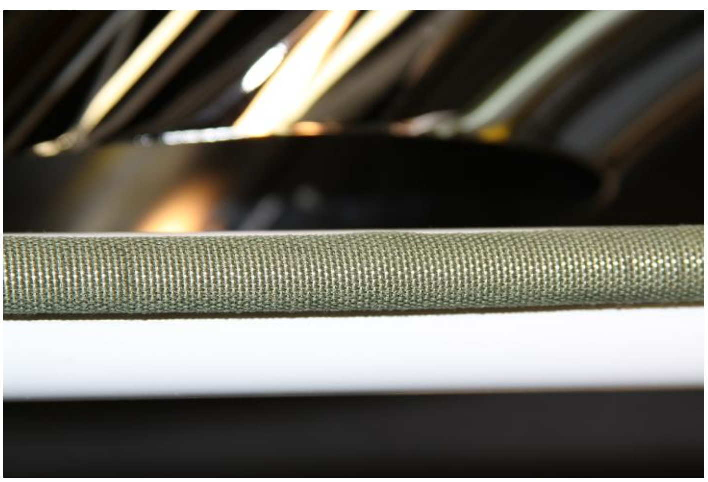
As the saying goes, "measure twice and cut once." I found that none of my dimensions took the thickness of the powder coat into account and a few major cutouts were completely wrong. I hope I caught all the mistakes. Laser-cutting these two panels won't be hugely expensive but I still want to get it right the first time. I also left out a push-to-test button for the rotor RPM alarm I'm designing. I put that above the rotor RPM indicator.

Tomorrow I'll go over everything one last time and then send the file off to have the panels cut. The next order of business is to select the color. I want a flat non-reflective dark gray. I think a gray panel will help my eyes focus on the instruments easier than searching through a black panel where all the instruments are the same color as the panel. That should make the instruments pop out as I scan.

I should have the panels back by next Wednesday. In the meantime I've moved the Genie Lift to the other side of the frame so I can get a better look at the left side of the engine and frame.



Now that the Genie Lift is out of the way I can look straight down at the clearance between the oil filter bracket and the frame. I realized that I failed to consider the fact that the frame slopes inward towards the back. I'm going to trim the bracket along that red line to give myself more clearance.

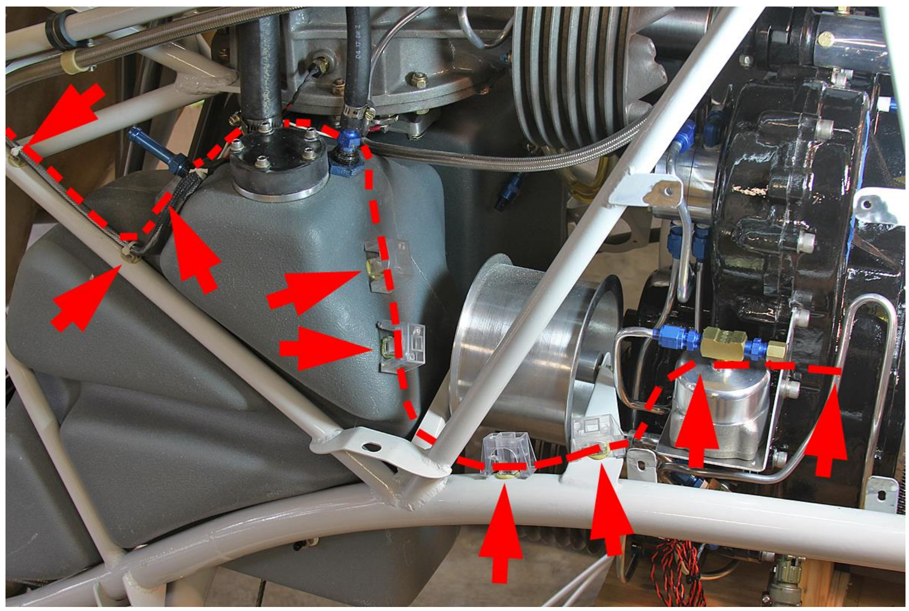


I'm also rerouting everything that passes over the tail pipe to the top of the frame tube and protecting it with the Nomex version of Roundit.

I'll epoxy a few more Click-Bond tie fasteners to the top of this frame tube to secure the bundle in place.

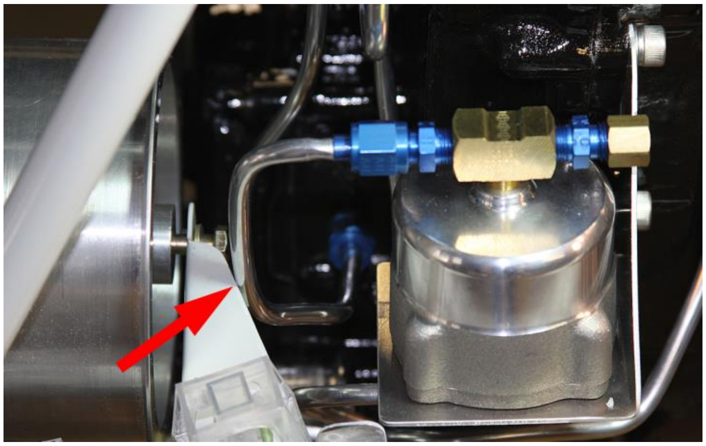
There are only three cables passing over the tail pipe – the tail rotor pitch cable, tail strobe light power and the VHF communications antenna coax. The last two are Teflon and can take considerable heat, but I don't want my tail rotor control cable to seize up and I doubt resistance to high temperatures was high on the list of criteria for that cable.

You can see how the Roundit works. It naturally springs back into shape as you work it around the cables. As long as the white tracer thread is covered by the other side you're using the correct size.



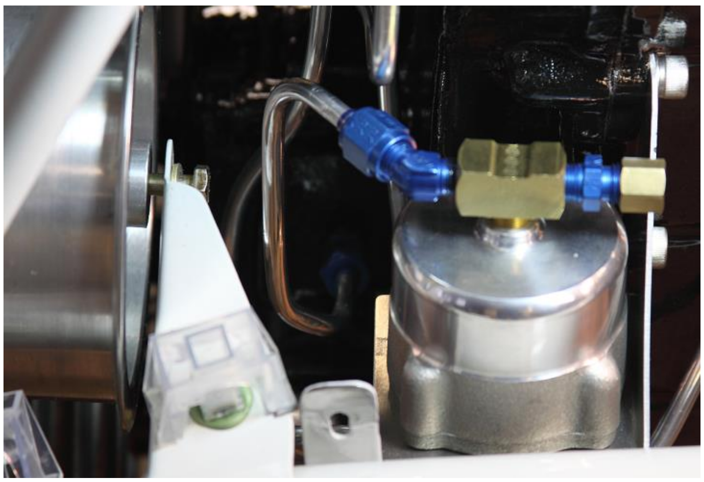
31 December – In the area around the idler pulley I've decided on my cable routing. I've epoxied seven additional Click-Bond cable tie fasteners to the frame and the tank (arrows.) The two on the right are on the back side of the engine controller enclosure which is removed for this picture. Where the bundle goes around the back of the black fuel probe at the top of the tank the bundle will pick up the fuel probe, transmission temperature, and transmission chip detector wires.

Nothing really extends aft past the midpoint of the engine so this may be all I need to bundle and route cables along the frame, but I still need a few more on the engine. I'll bundle these cables up using the same Nomex Roundit.



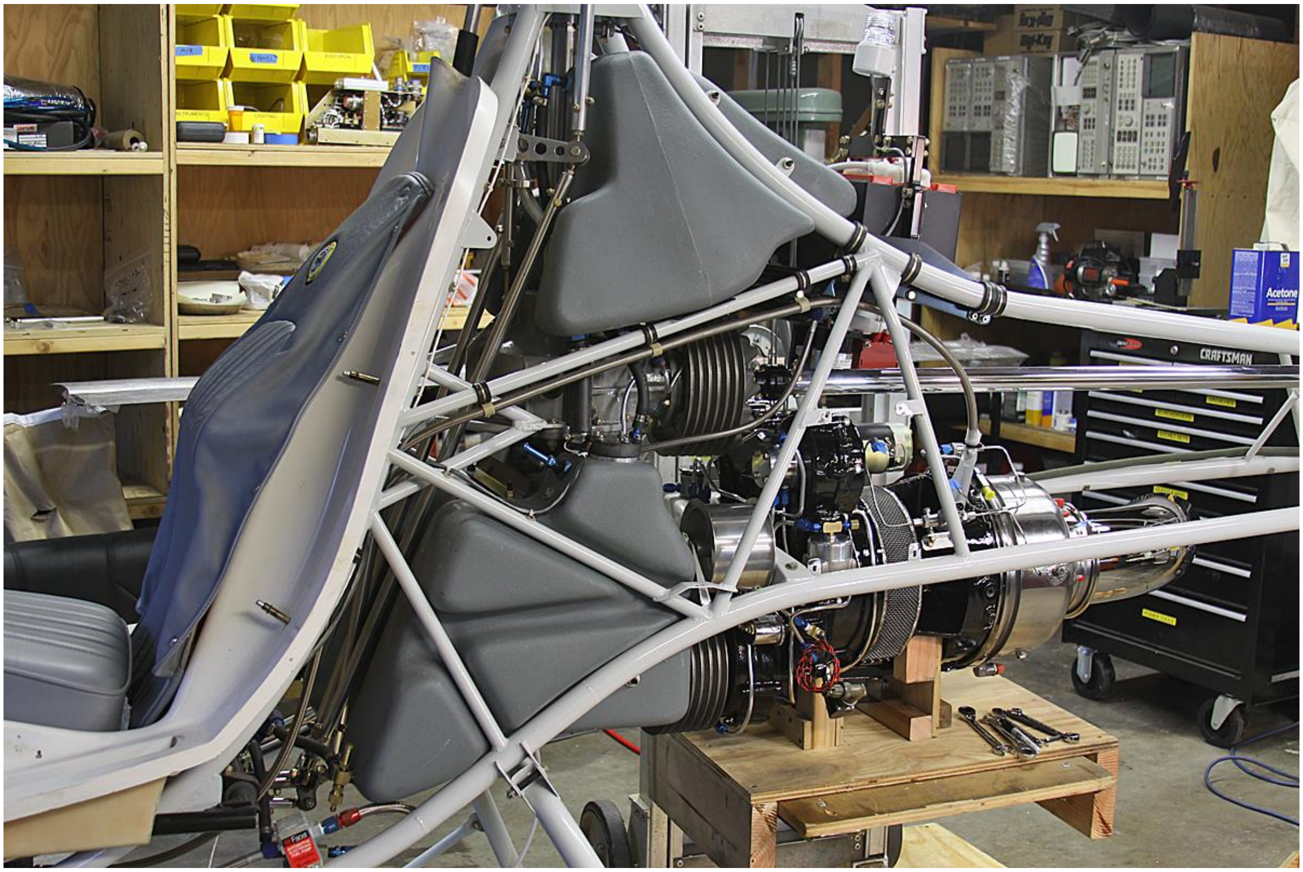
I was admiring my Photoshop work on the last picture when I noticed an interference problem – an oil filter line is rubbing against the side of the idler pulley bracket. That won't do so I'll come off that 'T' with a 45° AN fitting and bend up and flare another piece of tubing.

Don't be alarmed by the loose idler pulley bolt. The pulley is sitting in position for a fit check and it's not installed.



Here's the new design with the 45° fitting on the oil filter. I still need to trim the bracket and paint it, clear-coat the filter, and final install all of the fittings using Teflon tape.

Year End – 2009



This is where the project stands on the last day of 2009. The third-hand kit arrived in my driveway at the end of July 2008. I've been working on it steadily for about fifteen months and probably have twelve hundred to fifteen hundred hours into it at this point. The project is fairly far along. Here's a list of work remaining:

Engine: The fuel control unit should arrive in a few weeks. It will need to be cleaned up as much as possible and then installed on the engine. Once that's done the engine is ready to go. The next task is to clean up all of the clutch and engine mounting bracket parts and paint or chrome plate them. Once they are ready to go the engine can be installed on the frame.

Instrument Panel: I'll have the laser cut panels early next week. Then they'll get powder coated, and I might have the legends silk screened on and then a clear coat over that. I'll have to see what that will cost. I have all the instruments, switches and circuit breakers and the assembly will go fast. Mounting the panels into the pod will take some time to get just right but it should be easy.

Wiring: My wiring plan is complete except for a few small details. Wiring the entire ship should take about two weeks.

Fuel: I'm going to replace all of the 3/8" fuel lines with Tygon F-4040-A which is rated as "good" for kerosene and jet fuel. Only Viton is rated "excellent" and it's only used for o-rings to my knowledge. Hap has had trouble with the material supplied by Eagle and I don't like Neoprene since it's not even rated for use with jet fuel. I also have to install my aux tank and fix a few problems with fittings at the bottom of my lower tanks and then the fuel will be complete.

Cabin: All of the fiberglass associated with the cabin needs to be painted. This includes the seat pan, the instrument pod, and then cabin itself (inside and out.) The doors need to be installed along with the wind screens. I'll have most of this pained by an auto custom paint shop as one of the last things on the list. I also need to install the seat back leather and add padding.

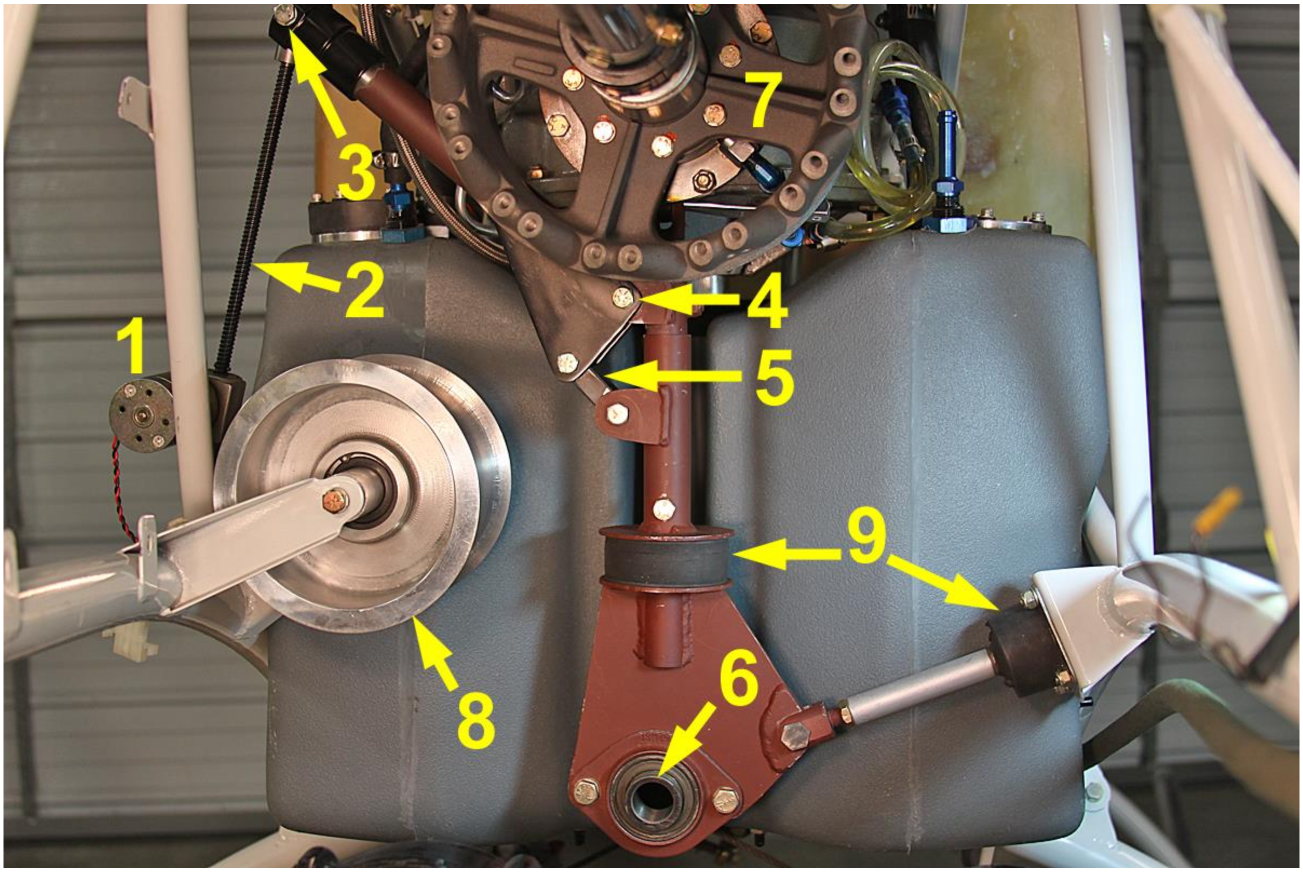
Tail Rotor: One of the paint shops I used many months ago decided to rough up the tail rotor blades using 80-grit sandpaper. All I wanted them to do was paint a black stripe on the end. I'll have to put some time into trying to buff out those very deep scratches and get the blades to shine again. Then the tail rotor can go back together.

Main Rotor Blades: These need to be polished and finished off with tip weights and other tweaks. This will also take some time.

Miscellaneous: Most of the controls need to be final installed and I need to decide what to do about my foot pedals after discovering corrosion inside the tubing.

Once all this is done the helicopter should be ready for an FAA inspection and then a factory checkout. There are a few remaining items like how and I going to get the helicopter out of my garage? Unless I decide to rent a hanger I'll have to buy a trailer to haul it and then a pick up truck to pull the trailer. And there is the small matter of getting back up to speed flying after a 19 year gap. I think I'll need about twenty hours of dual instruction in a Robinson R22 to get half way proficient at flying in the dense urban Bay Area environment again.

Tomorrow is a new year…

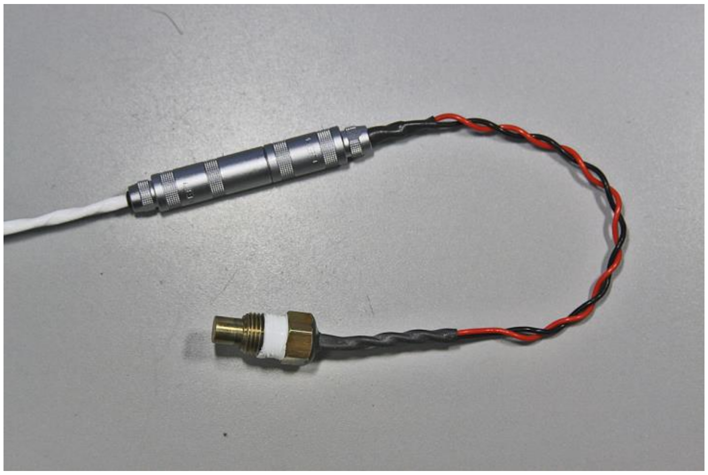


New Years Day – 2010 –

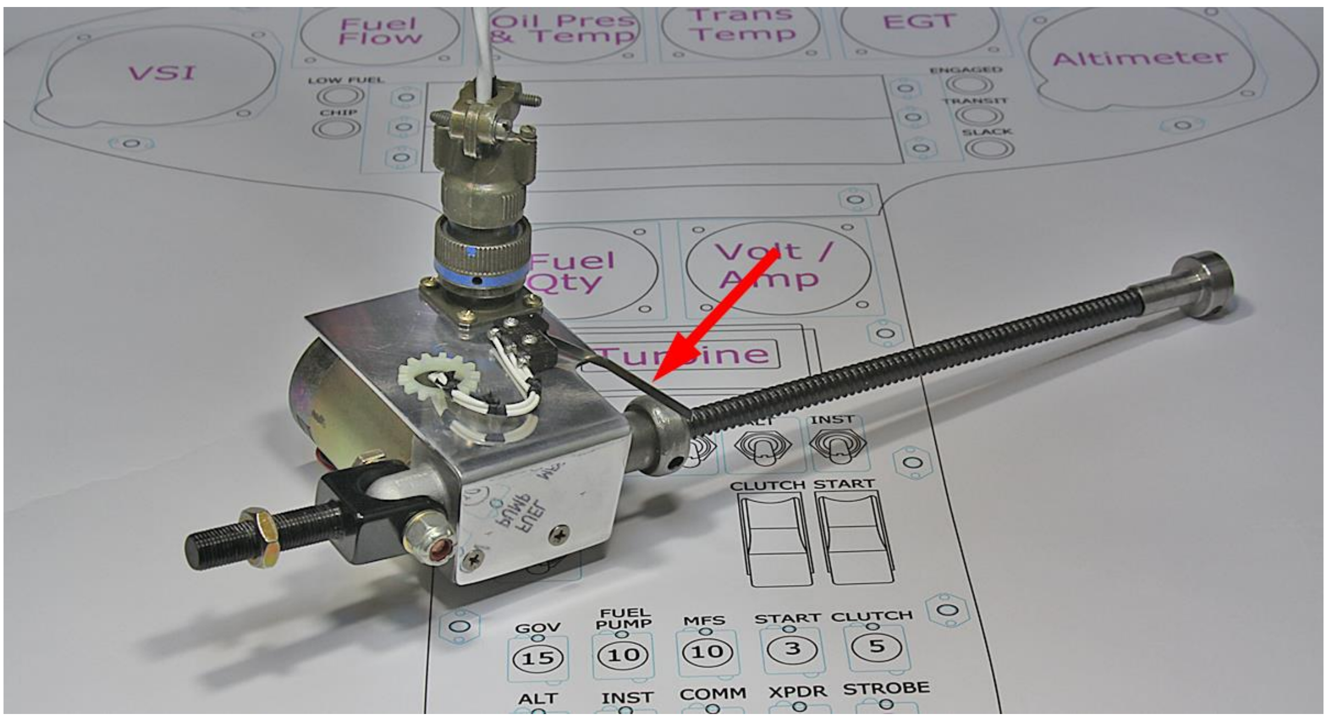
I've moved the engine out of the way and installed all the clutch components to see how they line up. Some helicopters don't need a clutch at all if their turbine engine has two separate shafts. But this engine has a single shaft so it would be like trying to start a car while it was in forth gear. It's too much of a load on the starter and the engine, so we need a clutch to unload the engine until it gets up to speed. Here's how it works: The clutch has a small electric motor (1) that goes through a gear box and turns a jack screw (2.) The end of the jack screw has a slip attachment that attaches to a lever arm (3) that pivots at (4.) As the lever arm is moved down to engage the clutch it pushes the clutch assembly down via the small link (5), stretching the belts until the small link goes over center. (The piece that attaches to (4) slides inside of the vertical tube that (5) attaches to.) At that point the clutch is fully engaged. The engine's shaft sticks out of the middle of the engine pulley and into the bearing at the bottom of the clutch assembly (6) where it is secured. The net result is that as the clutch moves up and down in its travel the engine pivots slightly on its mounts and the engine pulley is raised and lowered. The six v-belts go around the transmission pulley (7), down the inside of the idler pulley (8), and around the engine pulley. The two rubber bushings (9) compress slightly when the clutch is fully engaged. The purpose of the one on the side is to keep the engine centered. There will be two limit switches at either end of the jack screw that operate indicator lights in the cockpit so the pilot knows what state the clutch is in.

The next step in this project is to paint all the zinc chromated parts and then final assemble the clutch. This has to be completed before the engine can be installed.

Saturday 01 January 2010 –

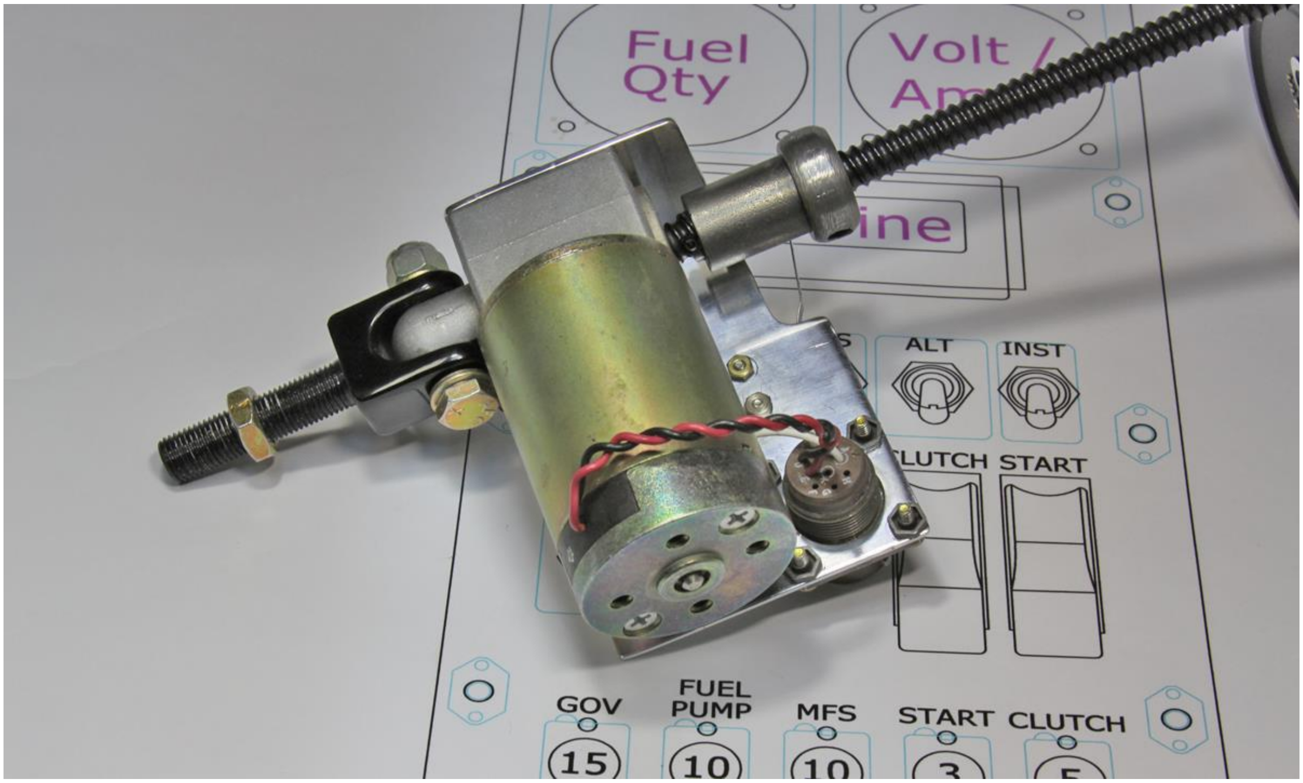


I have the engine temporarily mounted so I can start looking into how I want to wire the various engine controls and sensors. Every one of them can be disconnected by unscrewing a connector or disconnecting terminals, except for the oil temperature sensor. I thought it would be a good idea to be able to completely remove the engine without having to cut any wires so I looked through my junk pile and found a set of Nemo connectors. They’re made in Switzerland and they’re very nice in-line miniature connectors. That should work!



Sunday 03 January 2010 -- I spent the entire day making this bracket and mounting the parts. This is the clutch motor assembly which includes the jackscrew and the lower limit switch. The red arrow points to the limit switch actuator arm. When the switch is actuated a light in the cockpit will tell me that the clutch is fully engaged.

I’m using a different micro switch than the one provided with the kit. There’s nothing wrong with that one but I messed it up in the process of designing this and getting it put together. This little switch is rated at 5 Amps so it will be just fine. I came up with this idea because I don’t want to wire too many components into the wiring harness. This way I can easily remove this subassembly by simply unplugging it.



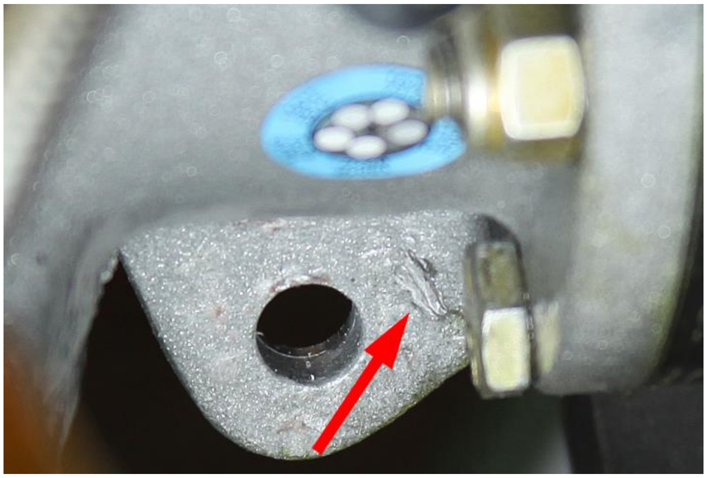
Here's the back side of the assembly showing the motor and gearbox, the connector, the mounting clevis, and the jack screw and follower. The follower has a clutch inside so it slips when it hits the end of its travel. I think it tilted a car seat in a previous life.

I'd include the AutoCAD drawing I spent an hour or so drafting except the computer locked up and ate it for breakfast this morning. Why does that always happen just as you think that it might be a good idea to pause and save your work?

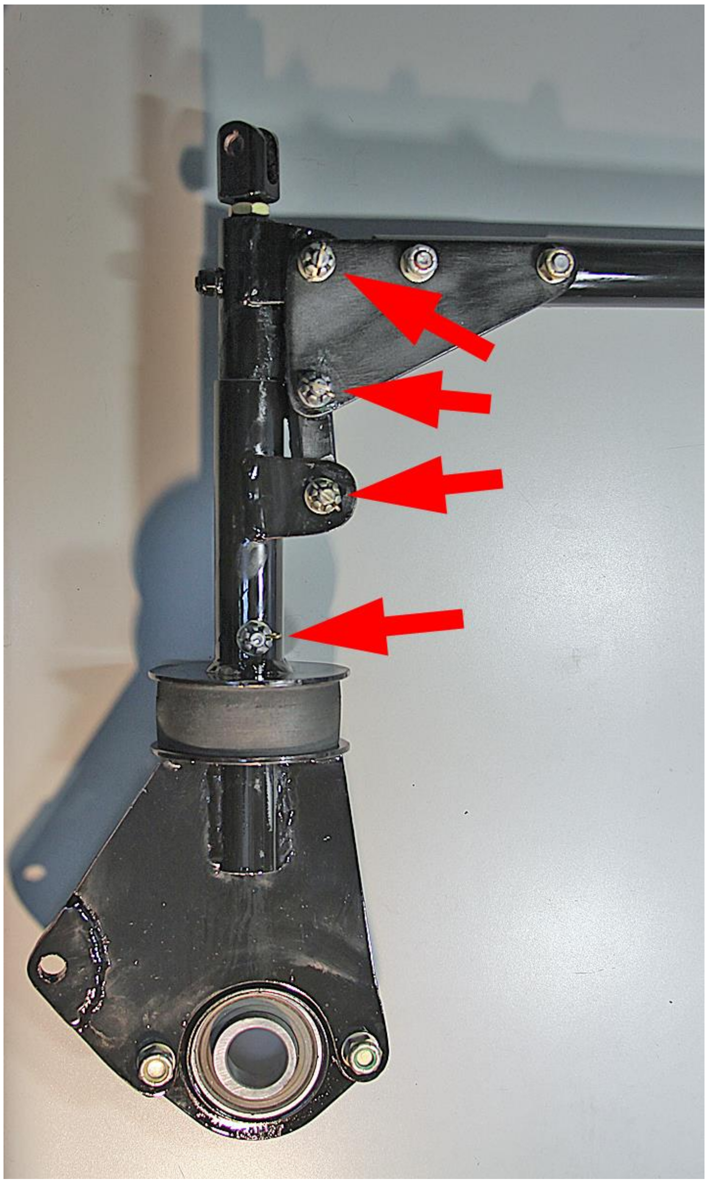
One more minor setback – I managed to break off the actuator on the micro switch so I'll have to use another switch and remount it on the plate. This shouldn't be much of a problem.

My pint of POR-15 black paint arrived. The preparation is a multi-step process. Assuming no rust, the first step is to go over all the parts with a Scotch-Brite pad and rough up the surface. Then they are washed in a diluted solution of Marine Clean and finally washed in Metal-Ready. Both are POR-15 products and can be purchased as a kit with the paint. In between steps I rinsed the parts in water and dried them off. The parts must be completely bone dry before painting since the paint sets up with moisture. This paint is unusual. The instructions say not to get any paint in the groove where the lid seals to the can or you’ll never get the lid off again, and to remove only the amount of paint you need to another container and then shut the can quickly. I didn’t take that seriously last time and found that there was a large lump of cured paint in the can the second time I opened the lid. This time I used a piece of fuel line to suck paint out of the can and into a smaller cup. I held my finger over the end of the line to keep the paint in and then released it when the tube was over the cup. That worked well. This selection of parts took less than one ounce of paint.

Here are the parts after painting with a brush. Brush marks aren’t much of a problem but the paint does tend to slowly flow and end up at the bottom of the part. I tried to dab off the excess paint at the bottom of each part before leaving the parts to cure over night. That helped. I also used a very cheap brush and I had to constantly pick loose hairs off of my parts. I’ve been using disposable gloves for just about everything I do that is messy and they worked well here. Once that paint dries on your skin nothing will take it off. It’s going to be there until the skin wears off.

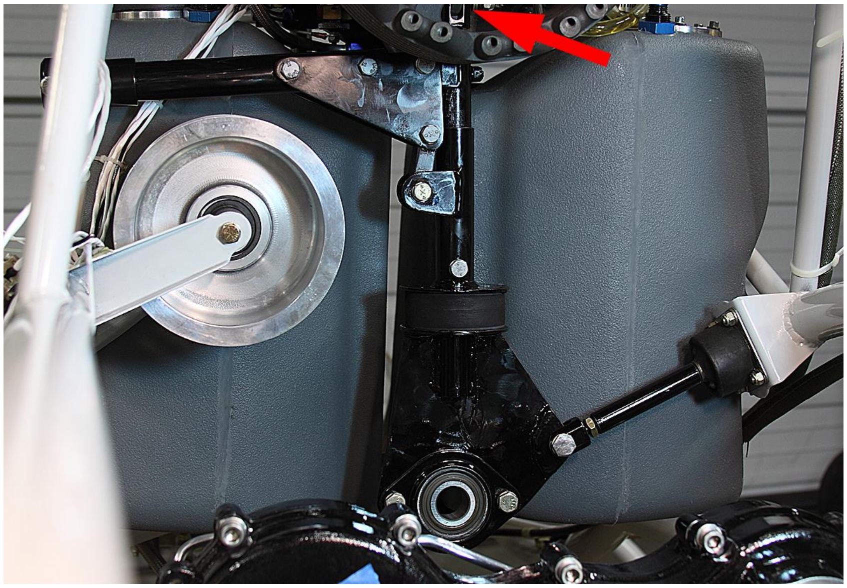


As I began to final-install the painted clutch components I remember having trouble getting the clevis at the top of the clutch assembly to mate with the boss on the bottom of the transmission. I took a close look and I can see some material on the surface that's interfering and has to come off. It's a tight fit but I should be able to get in there with a Dremel tool and a burr.



Here's the assembled clutch ready to install in the ship. I used castellated nuts in the four places where the assembly moves and lubricated those places with grease.

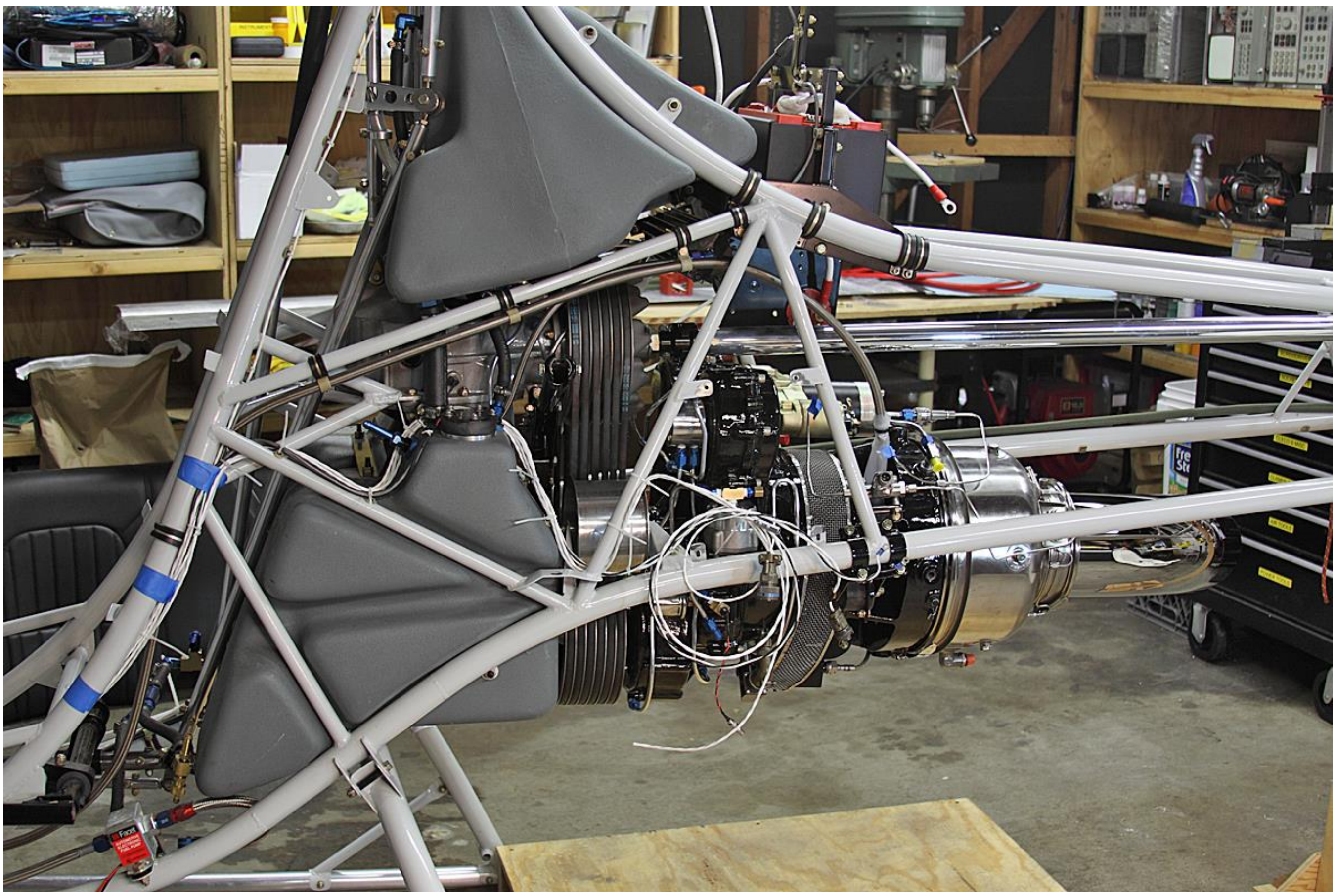
In the construction DVDs BJ doesn't seem to have a lot to say about the details of this clutch and there are no mechanical drawings. I decided on castellated nuts since it made sense to me. The top pivot point is formed by two side plates surrounding two ears that are welded to the top piece of tubing. I'd expect a spacer in there to keep builders from over tightening that bold and squashing the ears together. The piece of tubing that forms the handle prevents this from happening to an extent so perhaps it's not necessary.



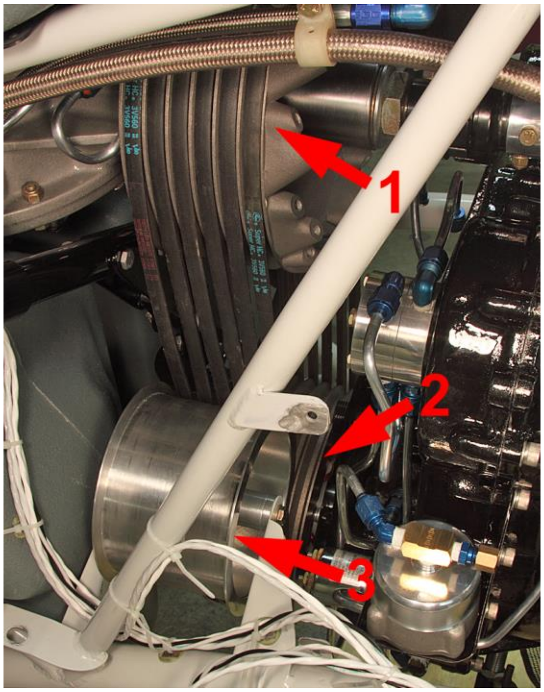
Looking forward, this is the clutch going into the frame for perhaps the last time. Items to note:

- Painted using POR-15
- Lubricated moving surfaces with grease
- All bolts face forward
- Castellated nuts and cotter pins on all bolts that need to be slightly loose
- Engine bearing flanges on aft side
- Long side of bearing towards front

In the picture above, the arrow points to the clevis that connects the clutch assembly to the bottom of the transmission. The arm extending to the right is used to center the engine in the frame. It's adjusted to give the oil sump ¼" clearance to the frame tube on the right.



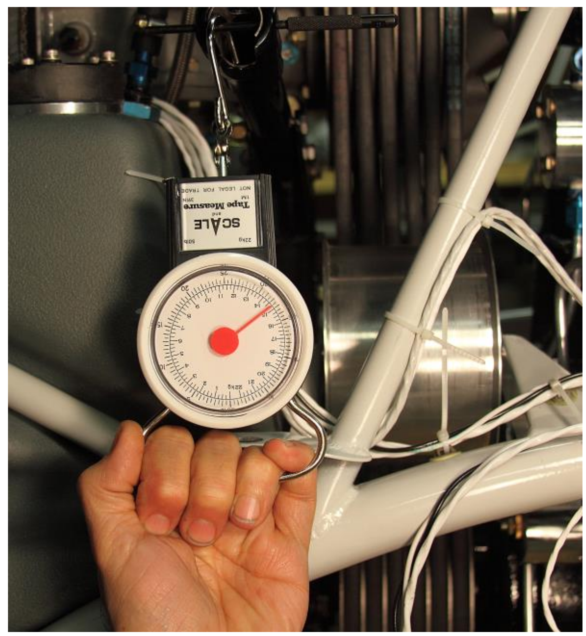
Sunday 10 January -- The bearing at the bottom of the clutch (bottom of top picture) moves down as the clutch is engaged, and the engine pivots on its mounts. Each mount is attached to the lower frame tube by the two black brackets seen in this picture.



All the installation adjustments are tied to the alignment of the transmission pulley (1.) The engine must be aligned in all three axis so the engine pulley (2) is exactly parallel. The same goes for the idler pulley (3.)

At the same time the engine has to be centered in the frame, with ¼-inch of clearance between the frame tube and the side of the oil sump. And all this must be done after the clutch engagement force is set to thirty eight pounds.

I'm working at a disadvantage since all the mounting holes in the engine mounts were already drilled by a previous builder. I have some wiggle room but not as much as the builder of a new kit. If I'm too far out I'll have to make some new bracketry.



Once the engine is installed, and all the belts are in position, the first order of business is to adjust the clutch tension to 38 pounds. That's the target force required to pull the clutch lever arm to the fully engaged over-center position. The top clutch clevis where it connects to the bottom of the transmission housing is adjusted to bring this force into range. Once this is dialed in the rest of the adjustments can be made.

The Mitutoyo Pro 3600 protractor is a fantastic tool for checking pulley alignment. The only tricky part is getting the protractor aligned with the axis of the pulley. This idler pulley is easy but the other two are a bit harder because of all the obstructions.

The table below shows the results of my installation. I began by tilting the frame back on its skids to make the transmission pulley parallel to the ground. The angles in parenthesis are normalized to zero out the slight remaining angle of the frame. With a bubble level this wouldn’t work but with the digital protractor I don’t really need to level the transmission. It just makes getting it into position on the Genie Lift easier.

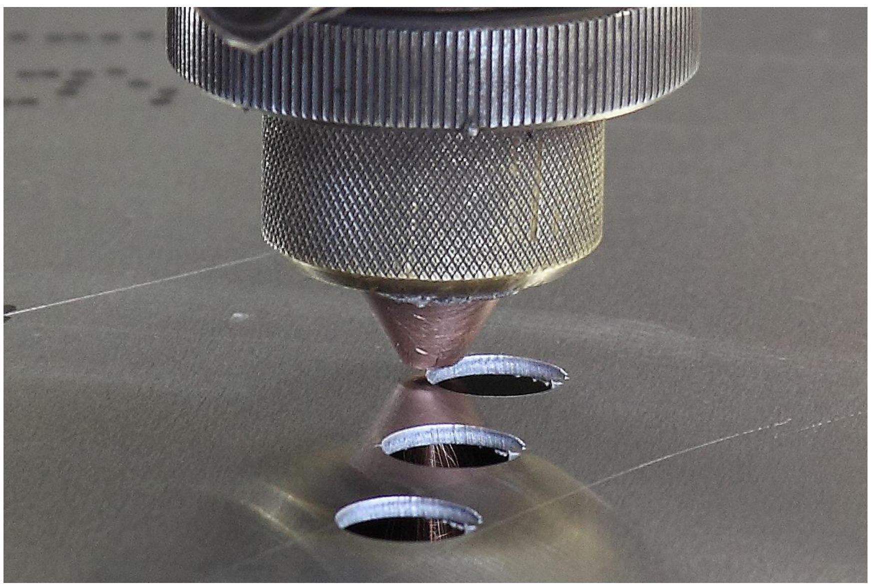
MEASUREMENT	VALUE	COMMENTS
Clutch Engagement Tension	36 Pounds	Adjusted with top clutch clevis.
Transmission Pulley Angle	-0.69° (0.0°)	After tilting ship back on skids.
Engine Pulley Angle (Clutch Engaged)	-1.37° (-0.68°)	The best possible using existing mounting holes. New brackets would be required to improve this.
Engine Pulley Fore/Aft Alignment	0.05” Aft	Fwd faces of engine and transmission pulleys.
Idler Pulley Angle	-0.49° (+.20°)	See picture on previous page.
Idler Pulley Skew	0.20” Both Sides	Straight edge across the back of the pulley and across belts on both sides of pulleys.
Idler Fore/Aft Belt Alignment	0.1” Forward	Where the belts ride inside the pulley.
Engine Rear Alignment w Frame	L=4.2”, R=4.0”	Measured from combustor to frame
Oil Sump Clearance	0.25”	Adjusted with rod on side of clutch assembly.

This looks pretty good to me. The pulleys are three inches wide. With a skew of 0.68° the difference from side to side is only thirty six thousandth of an inch.

(I checked with Blake at Eagle R&D a few days after I wrote this and it’s not good enough – at least I don’t think so. The clutch engagement tension has been increased to 42 pounds since the construction DVDs were made so that will change things a bit. And in spite of my notes I can’t tell from them whether the front of the engine is too high or too low. Adding tension will lower the front which might improve the alignment, and as the belts stretch the alignment will change. I’ll probably get new engine mounting brackets and then I’ll be able to drill my own holes instead of being stuck with that a previous builder left me.)

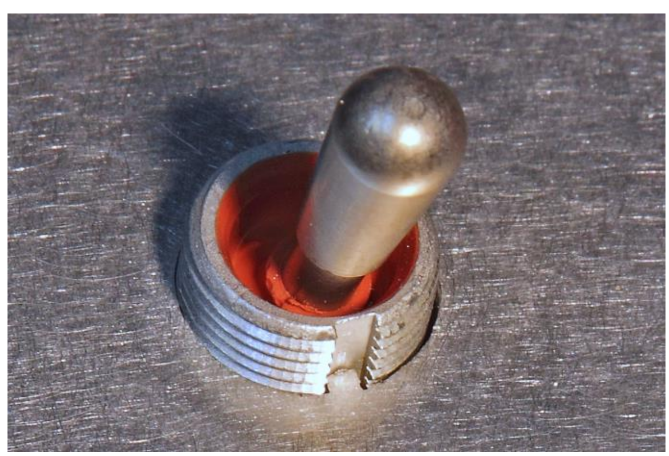
Builder's Log – Helicycle N750G

Now for a slight change of subject – Friday I sent my AutoCAD instrument panel design to Pega Precision up the road in Santa Clara to have them laser cut it. The machine is impressive. It has a huge bed that the material mounts on. The bed travels left and right and the light blue section with the cutting head moves towards and away from the camera (X and Y axis.) The industrial laser is housed in a large cabinet just barely visible to the extreme left of the picture. The laser light is piped to the cutting head via a complicated optical path. This machine is capable of cutting something like ½" steel. In this picture it's just started running the instructions that will cut both of my panels.



The laser light is not in the visible spectrum but I could see occasional sparks as it cut. You can see some sparks in this picture. It took about two minutes to cut both panels. It seemed to cut about one inch a second. The cuts leave a bit of debris on the back side that came off easily with an orbital sander.

In the picture above you can't see the small tabs, but here's another view of one of those holes showing the detail that the laser is capable of. The tab keeps the switch from rotating in the hole. That slot is 0.075", or about as wide as a dime is thick.



Juan Rivera

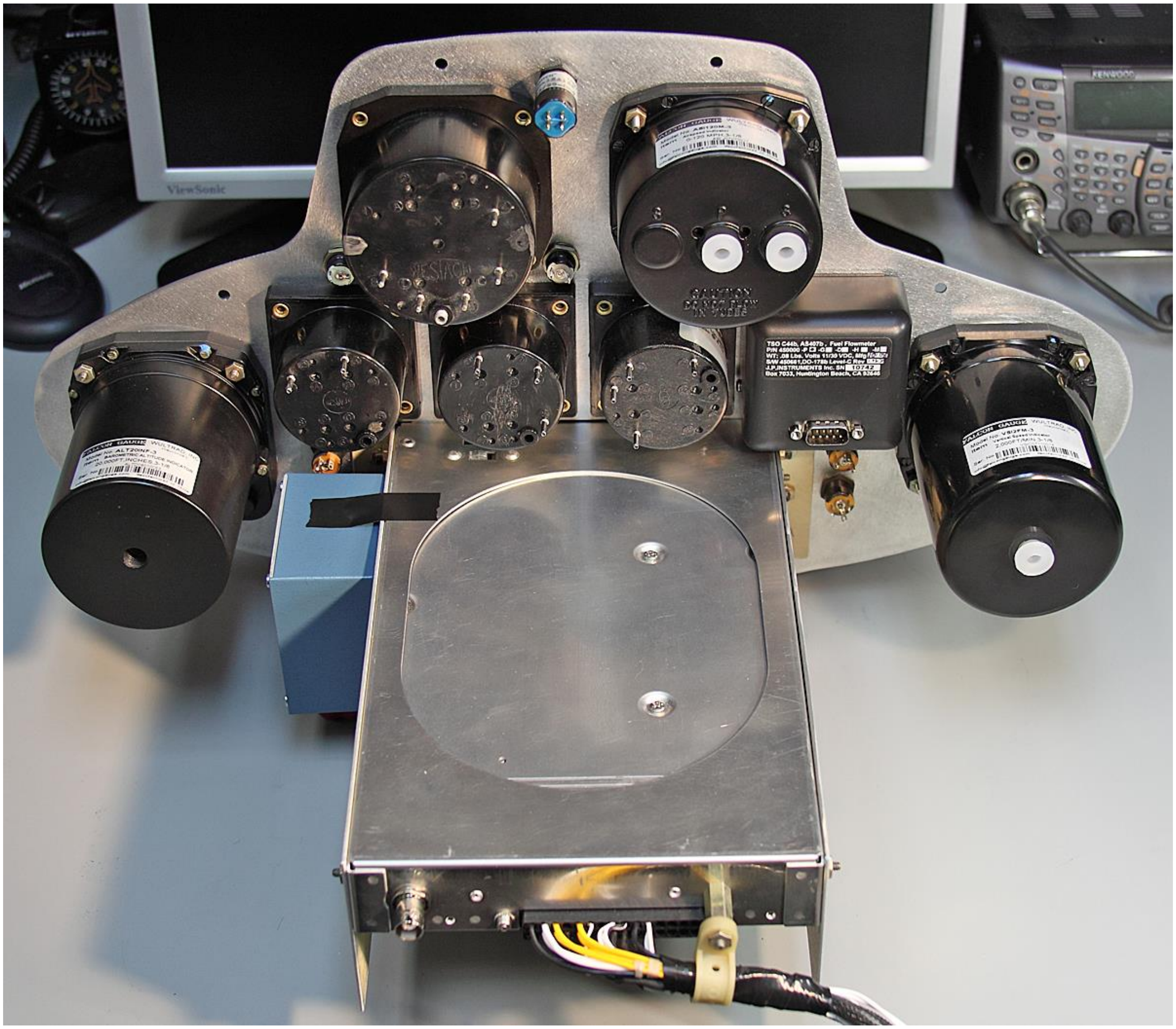
I populated both instrument panels with all of the instruments, switches, circuit breakers, and lights so I can check fit and interference, and to get a picture. The picture is on the next page.

I had to do a bit of filing here and there but nothing drastic – mostly around the vertical speed indicator and the altimeter. I didn't get that nub that sticks out quite right. The laser can only do what the file I drew told it to and my drawing was off a tad. The two radios at the bottom of the panel are heavy and they are going to need some bracing. The front brackets aren't going to be enough.

I still haven't decided whether to have the instrument panels powder coated or anodized. If I decide to anodize I'll bring the panels back and have Aaron grain them for me.

Contact info for Pega Precision:
Aaron Fast (Vice President)
2222 Ronald Street
Santa Clara, CA 95050
(408) 988-8373
Email: aaron@pegaprecision.com

Airspeed Indicator: The airspeed indicator uses the difference between a pitot tube and a static air input to determine indicated air speed (IAS.)
Rotor RPM Indicator: This is a critical indicator and that's why it's large and on top. I designed a rotor RPM alarm that will back this indicator up. The lights on either side below this indicator are low and high rotor alarms, and the button above the indicator is the push-to-test for the alarm.
Vertical Speed Indicator (VSI): This indicator used the static air input to display rate of change in altitude.
Fuel Flow: This is a digital display that shows fuel consumption in gallons and pounds per hour as well as fuel and time remaining.
Engine Oil Pressure and Temperature: This is the same as a car.
Transmission Oil Temperature: This monitors the main transmission oil temp. Since helicopters run at full power continuously the transmission is under much more stress than a car.
Exhaust Gas Temperature: This is a key turbine engine parameter.
Altimeter: This indicator also uses the static air input to determine altitude above mean sea level (not terrain.) It's called a "sensitive altimeter" since it has a knob to adjust it for the local barometric pressure. Without this adjustment it would be very inaccurate.
VHF Communications Transceiver: This is the two-way radio that is used to communicate with air traffic control.
Altitude Reporting Transponder: This device transmits a coded series of pulses whenever it's interrogated by a ground site or another aircraft. It sends the four-digit code that air traffic controllers assign to the aircraft as well as its altitude. This information shows up on the ATC radar as a data block that follows the aircraft. Other aircraft can use this data for collision avoidance.
Warning Lights: I have lights for low fuel, metallic chips in the transmission, and the state of the clutch. The lower instrument panel has three more indicators to monitor battery voltage and current, fuel quantity, and engine RPM.



I'll mount the rotor alarm circuit board in the blue Pomona box shown taped to the radio tray. The tray will need support since those two radios are heavy. One good pot hole on a trailer or a hard landing and the panel would fold up like a potato chip without some support at the rear. I can either run a beam across from side to side and attach it to the pod or perhaps extend a triangular piece to the front and attach it at the top of the panel.

This is the lower instrument panel. Of course once these panels are powder coated or anodized everything will be labeled – either by silk screen or press-on labels.

These two instruments are fuel quantity and voltage and current.

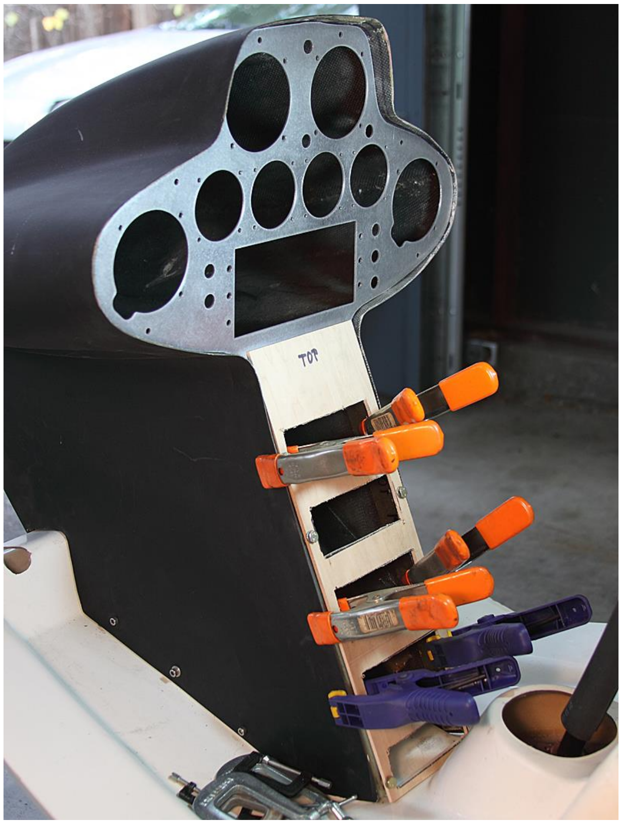
This is the digital engine tachometer. The engine runs at 61,091 RPM.

All of the various subsystems are powered from these switches. The two red-guarded switches are for the starter and the clutch. These are controlled from switches on the cyclic grip. To avoid accidental activation in flight these circuits will be shut off after engine start and clutch engagement. This is done by flipping the guards down as seen here.

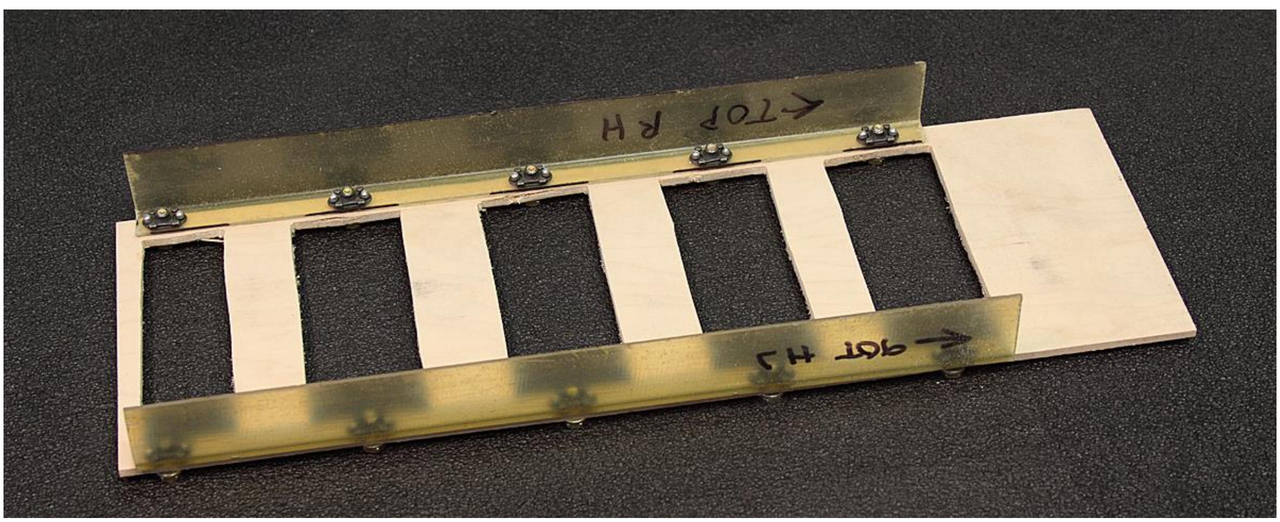
These are the circuit breakers for the various subsystems. These particular breakers are temperature-compensated so they will continue to operate correctly at elevated temperatures.

I forgot to order one circuit breaker. This is a one-amp breaker that feeds the fuel flow indicator on the top panel. It goes in the hole at the left.

This is the Hobbs running time meter. The clutch-engaged switch will activate this meter so I can track how many hours the helicopter has been operated under a load. This is used for maintenance and tracking flying hours.

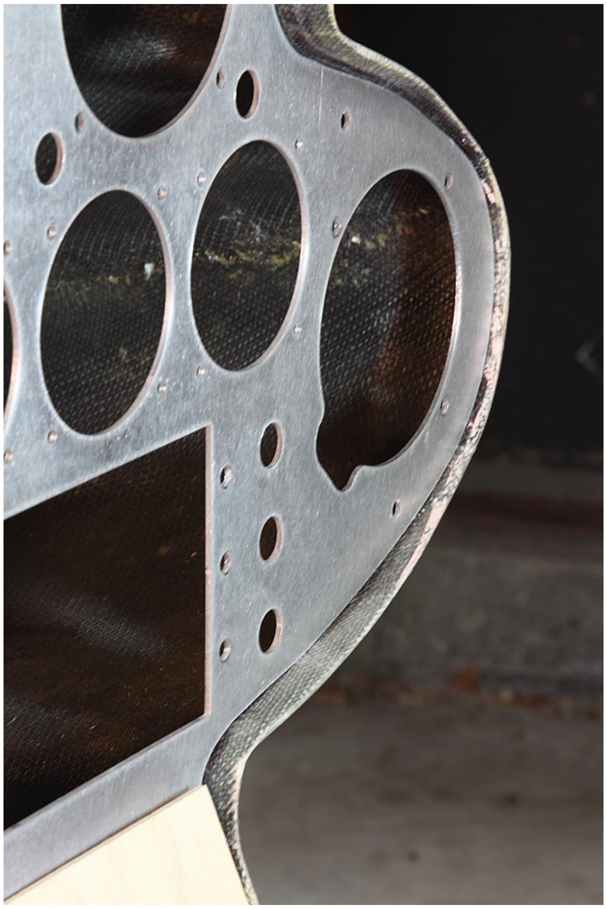


Saturday, 16 January 2010 -- I've been very carefully using my deburring wheel to tweak the outside shape of the upper instrument panel. The CAD drawing was pretty close but the inside of the pod is uneven and unsymmetrical from side to side so it's tricky. If you look closely you can see a wavy bump in the middle of the top of the panel. That matches the inside of the pod perfectly. It's an example of what I've been doing. Also, you can notice that the right side of the pod doesn't seem to make sense. I've got the top panel tilted back on top and everything looks as you would expect until you look at the bottom of the pod where it comes around under the top panel. It's as if the outside of the pod was ground off. The fiberglass protruding out on this side of the panel should continue to get smaller and smaller and not start to get larger again towards the bottom. The other side doesn't do this. The same wavy issue shows up to a lesser degree on the bottom. It makes lining up the panels a bit trickier.

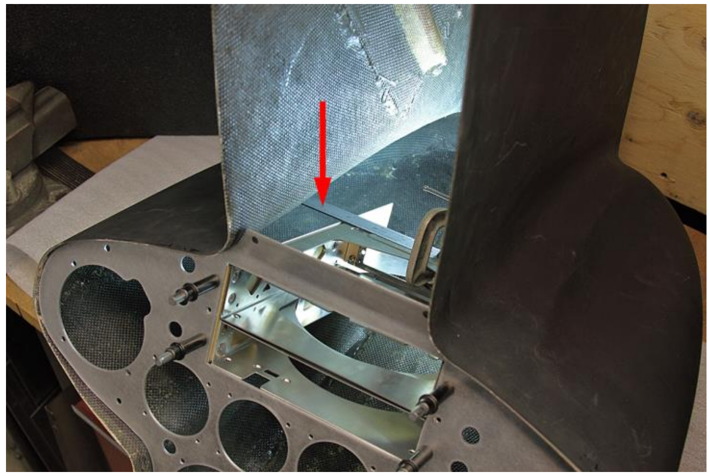


These are the two fiberglass rails that will secure the bottom instrument panel to the pod with the ten nut plates you see here. Normally I could simply bond these to ether side by lining them up with the front edge of the pod, let the adhesive cure, and then use the panel as a template to drill my mounting holes and install the nut plates. But because the front edge of the pod is slightly uneven I decided to make this fixture and go ahead and install the nut plates in the fiberglass rails first. The fixture will hold the sides in alignment while I bond the rails to the pod and the holes will allow access for clamps.

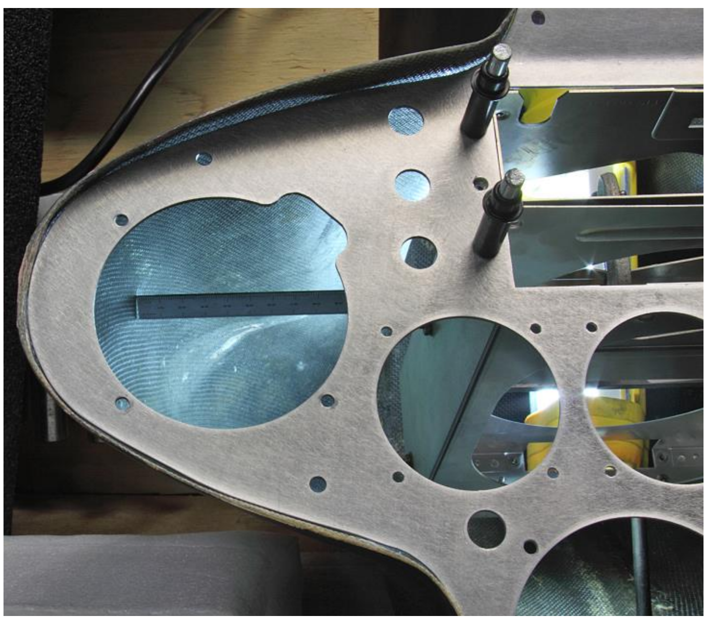
Installing the lower panel in the pod will subtly affect the shape at the top, so I'll wait and do my final tweaking of the outer shape of the top panel until after I have the bottom panel secured in place.



In the picture to the left you can see the uneven face of the instrument pod on the right side. I'll have to be very careful when I locate the panels and then come back and trim the pod to even out the face to match the panels.

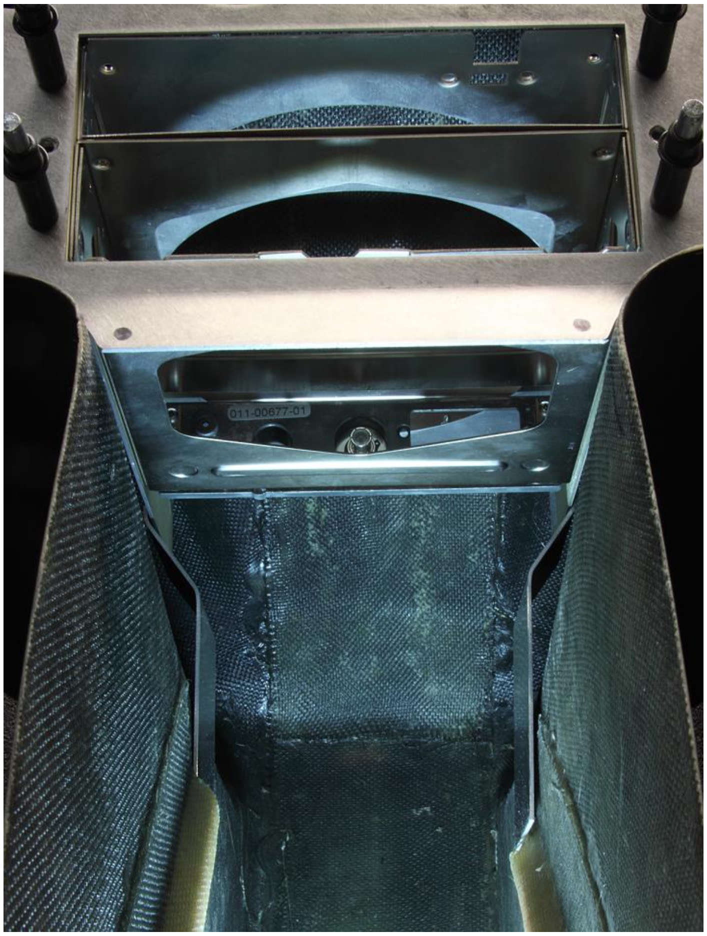


Here's the pod upside down. I've clamped a straight edge to the bottom rear of the radio tray to see how it will line up with the bottom of the top section of the instrument pod. I'll need support for the radios so I need a plan…



And here's a view looking through the altimeter mounting hole. There's nothing else back there so I can do whatever I need to. If the brace was stiff enough I could come all the way over to where the ruler touches the side, or I could mount to the bottom (top of the picture) about midway between the side and the edge of the radio trays…

Well, by the time I uploaded this to my web I realized that this is a bad idea from a structural perspective. I think I'll make a dog-leg piece on each side of the radio tray and come straight down each side of the lower instrument panel section where the walls are vertical. That should carry the loads straight to the seat pan without stressing the upper section which would want to constantly flex with changing loads. In the top picture you can see that the width of the lower section is almost the same as the radio trays so those support pieces can be almost straight. It will be easier to implement and I think that the simplest solution is almost always the best one.

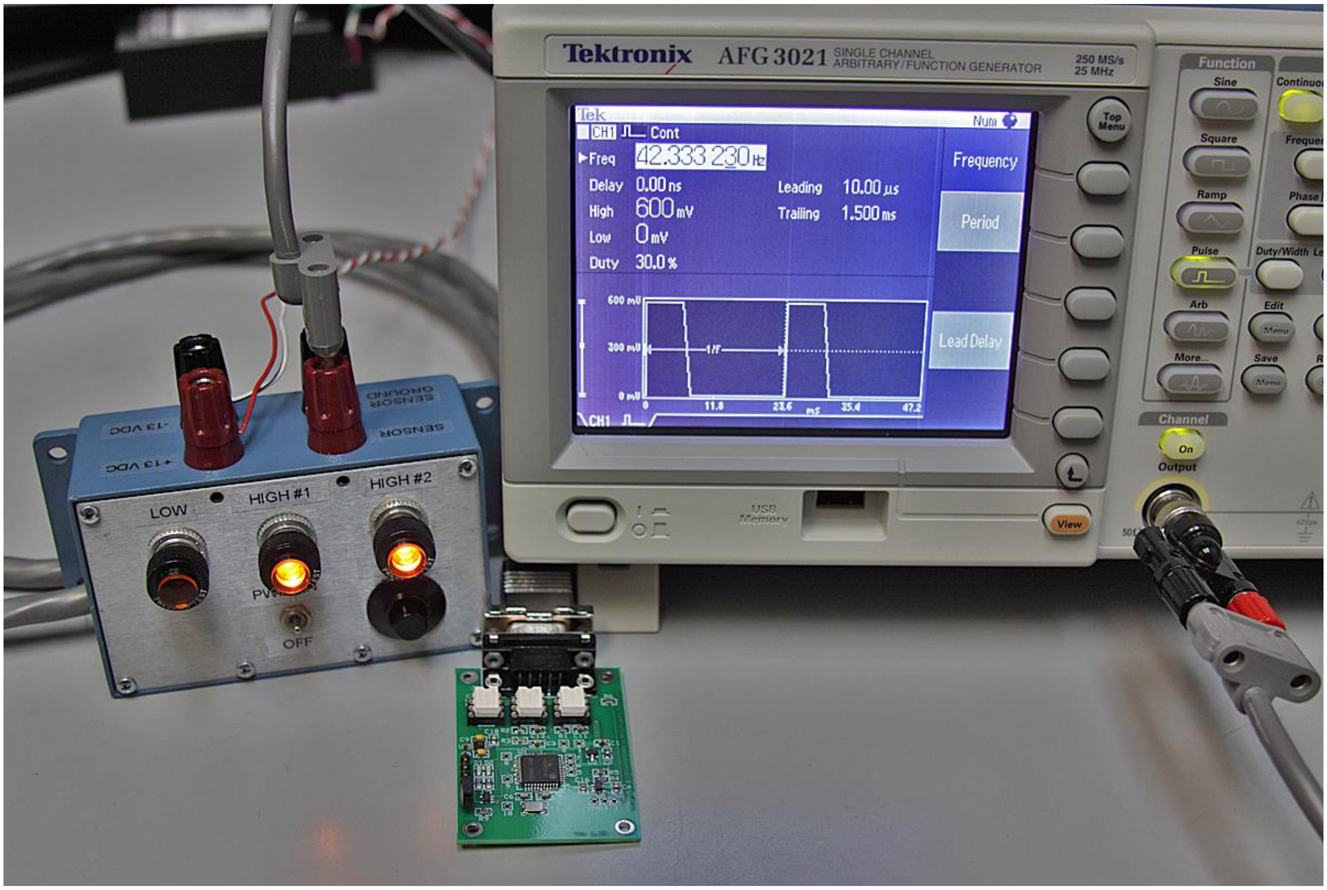


Sunday 17 January – Here's the new plan: I've flipped the pod right-side-up and now we're looking in from below, through what will be the lower panel. I made two brackets that have a 0.8-inch dog-leg so that they come straight down inside the vertical section of the pod. I adjusted the length of the brackets to account for the fact that the two wood braces are different lengths and partially block the area. The brackets are made from 0.060" 6061-T6 aluminum so they're stiff enough to get the job done.

I'll tidy them up and Alodine them once I get the mounting holes drilled, and then I'll secure them to the sides of the pod with several nut plates once everything is secured in place. That will be almost the last step.

I have many steps left in this instrument panel project: (as of 20 Feb not much left!)

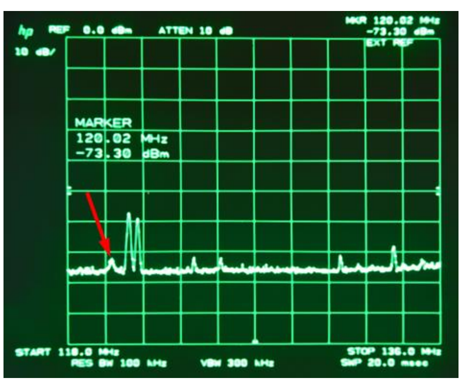
- ~~Mount the pod back in the seat pan and secure it with all the hardware~~ ✓
- ~~Bond side supports in place for the lower instrument panel using my fixture for alignment~~ ✓
- ~~Fabricate and install the bracket that secures the bottom of the lower panel to the seat pan~~ ✓
- ~~Match-drill the mounting holes for the lower bracket and mount nut plates~~ ✓
- ~~Mount the lower instrument panel to stiffen up the pod and get it into its final shape~~ ✓
- ~~Give the top panel's outer shape a final tweak now that the pod is stiffened and into its final shape~~ ✓
- ~~Bond the supports in place for the top instrument panel~~ ✓
- ~~Match drill the mounting holes into the supports and install nut plates~~ ✓
- ~~Mount the top panel~~ ✓
- ~~Match-drill the mounting holes for the radio support brackets into the pod's sides~~ ✓
- ~~On the instrument panels, double-check hole clearances to account for powder coat thickness and have both panels powder coated. (I'll drop off the oil sump at the same time.)~~ ✓
- ~~Install all panel components into the two panels~~ ✓
- ~~Fabricate wiring bundles for both panels~~ ✓
- Final paint the pod
- Final install the instrument panels and plug them into the interface chassis
- Check out ship wiring as it is installed



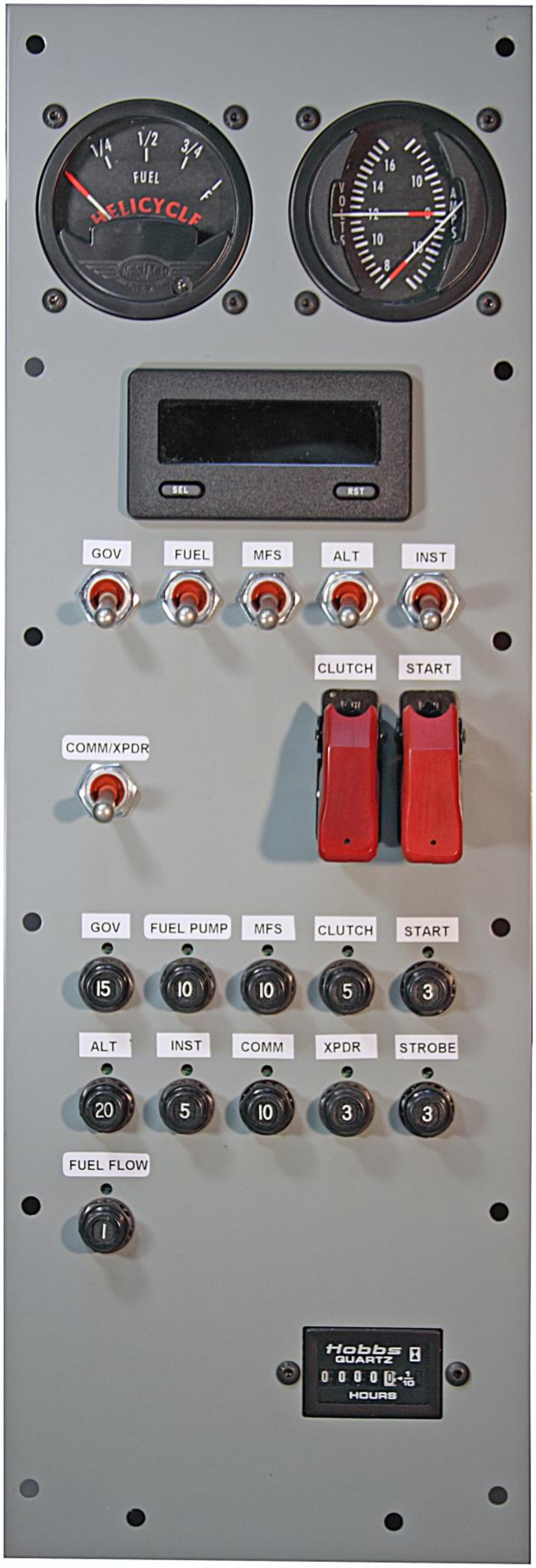
I used 3M Scotch Weld structural adhesive to bond the lower instrument panel side rails to the pod. The weather is cold so it will take two days before I can get back to that project.

In the meantime I made a component change to the rotor alarm circuit and ran it through trip point tests at room temperature. Here you see the input set to just set off the red line high rotor alarm (high rotor #2) designed to trip at 635 RPM. The input signal is set to 42.333230 Hz which translates to 634.99845 RPM. Is that close enough to 635 for you? The other trip points are equally close to 610 and 620 RPM – the bottom and top of the green, and since 135 RPM exceeds the 120 high rotor alarm #1 trip point, it is also tripped.

The oscillator runs at 20.000 MHz so the 6th harmonic is in the aviation band at 120 MHz. With the circuit board out in the open, and an antenna placed one foot away, this is what the signal environment looks like in the VHF aviation band:



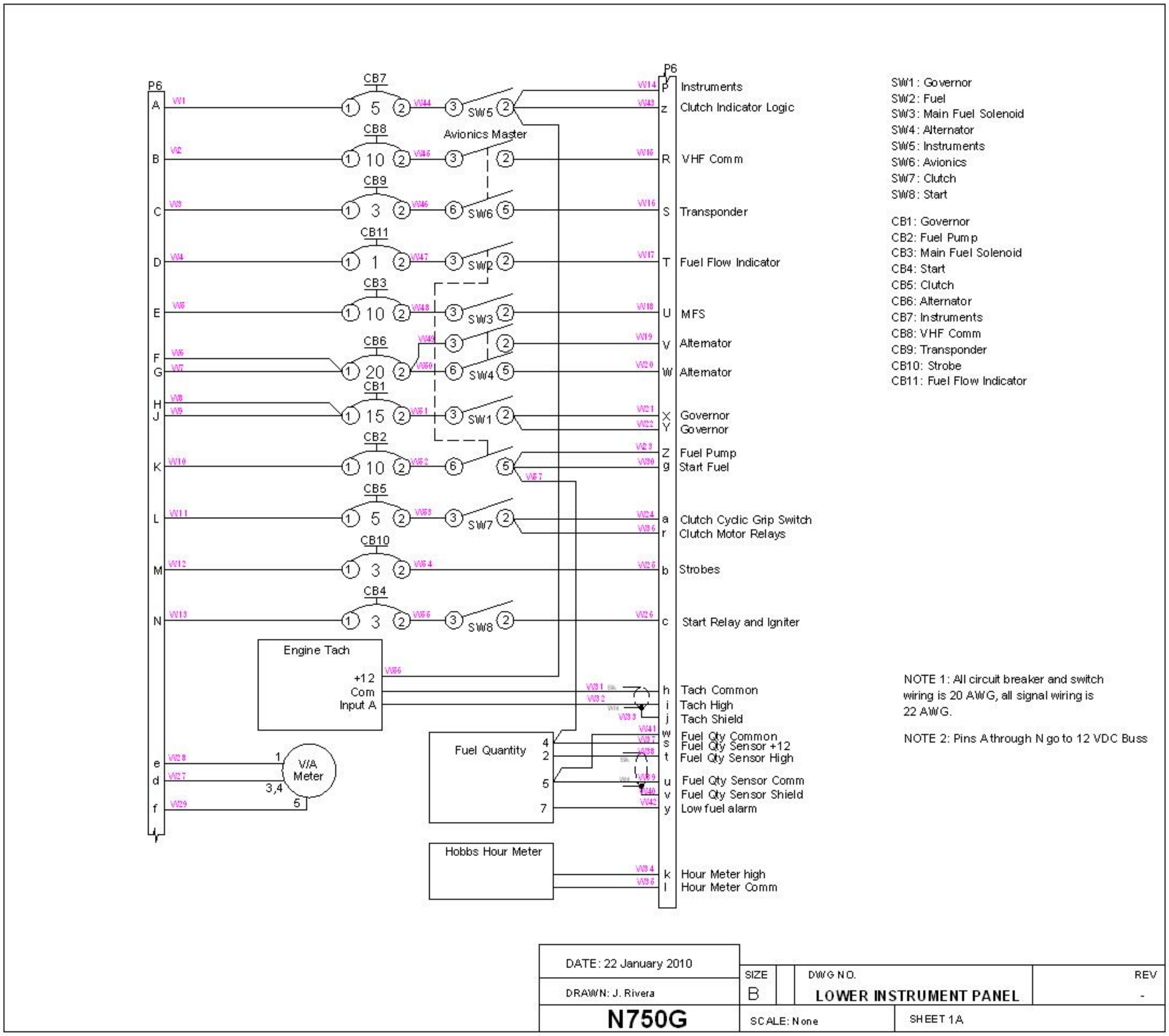
The red arrow points to the interfering signal at 120.00 MHz but you can see that there are several stronger transmissions on the band even though the antenna is only one foot away from the circuit board and it's not shielded yet. I don't think it will be a problem but since I plan to mount it right on the side of my radio I'll have to check again once it's in the enclosure. I'll also test it at -20°F and +150°F in my environmental chamber.



Friday 22 January 2010 -- I have my powder coated instrument panels back from the paint shop. I decided to try press-on labels that I can make at work before going to something more exotic like silk screen. These are easy to see and I can always change them later. These particular labels are Mylar or Kapton and usually hold up well.

I haven’t populated the upper panel yet since I’m still installing the fiber glass panel mounts on the pod and I’ll need to have that panel in and out several times before I’m ready to move forward. I don’t want to risk bashing an instrument so I’ll hold off installing them until the pod is ready and the radio support brackets are completed.

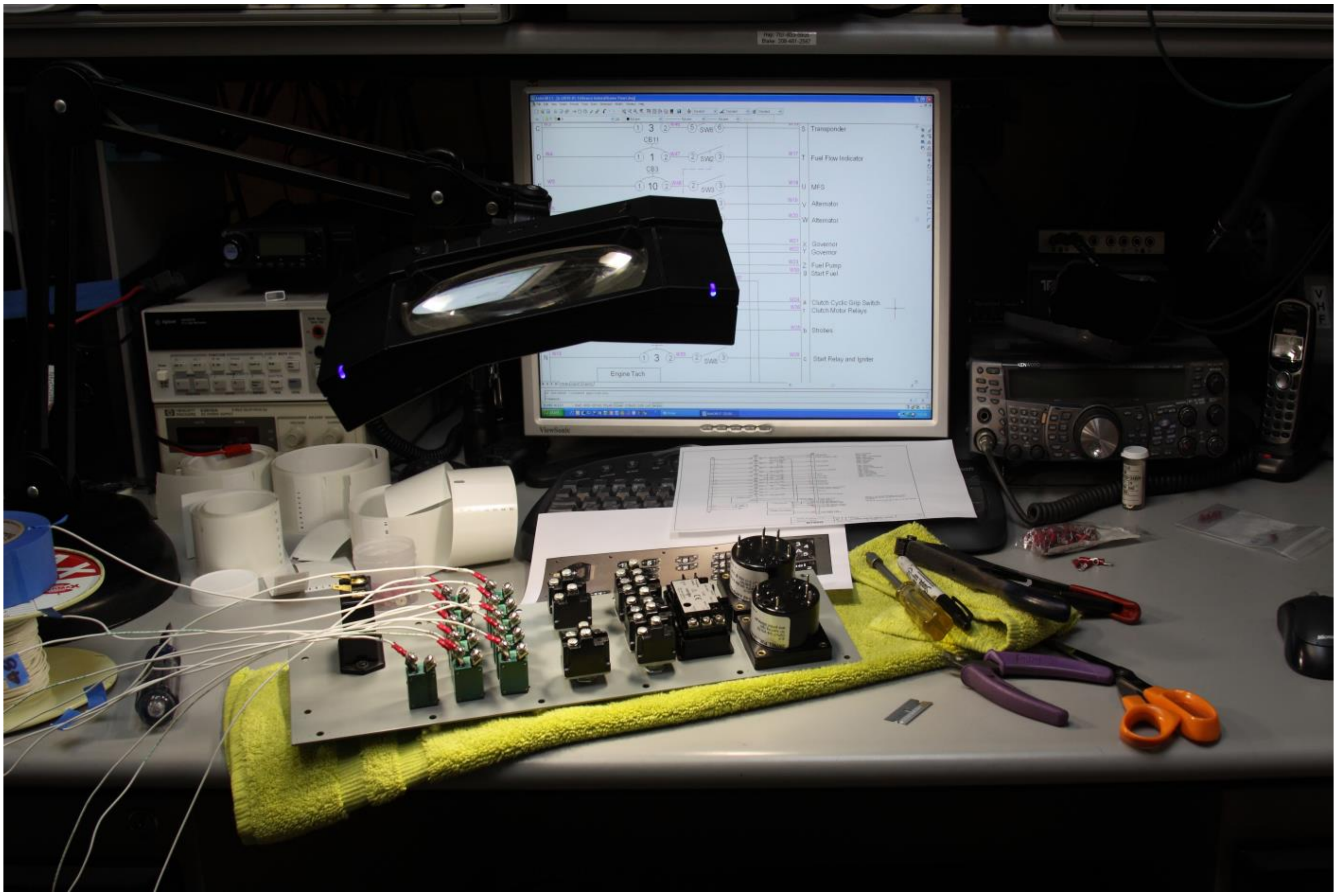
Meanwhile I’m about to start wiring this lower panel. This will be the first real wiring on this project and since all power flows through this panel, it’s a good place to start.



Here's the wiring diagram for the lower panel. Since I'll be using all white wire I've assigned wire numbers so I don't get confused as to which wire is which. Wire labels are a very good idea unless the wiring is very simple.

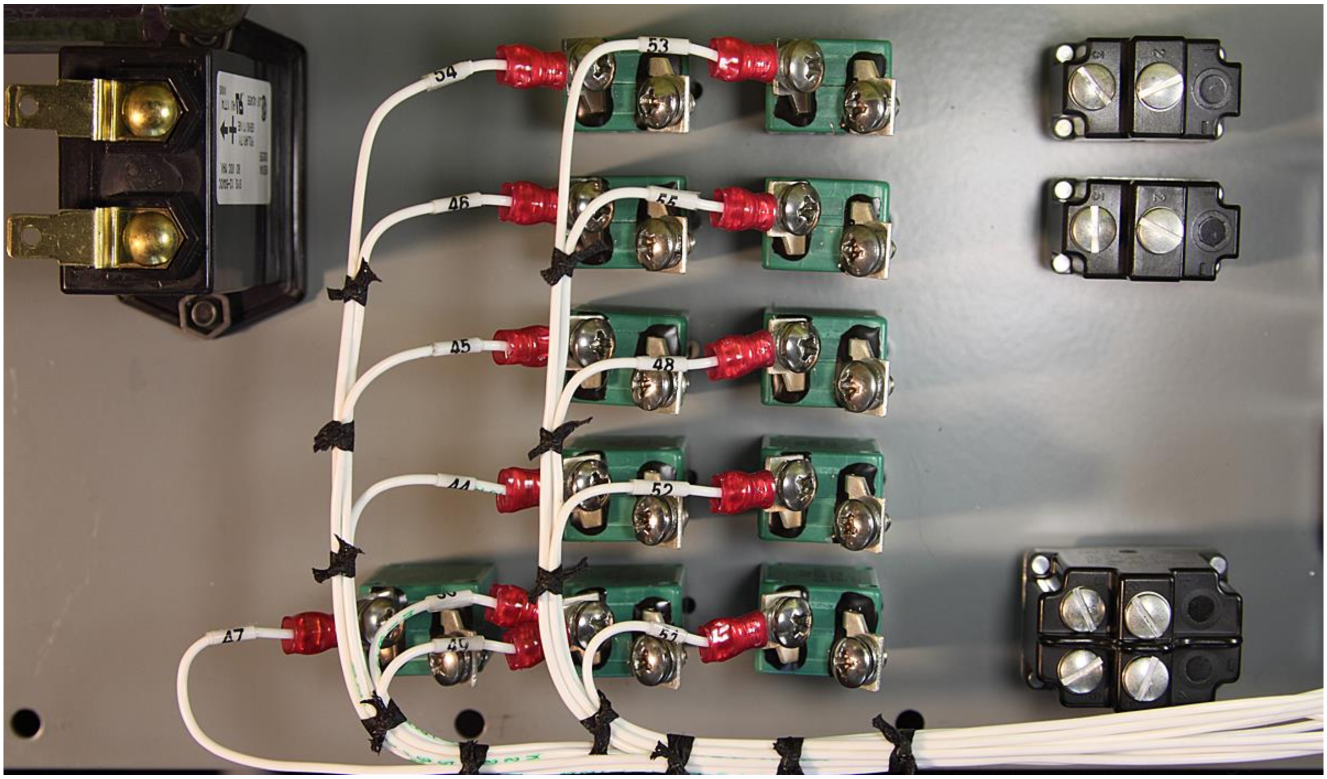
I'm running individual wires to each circuit breaker so I can pass them through a connector with small relatively low-current pins (Pins A through N on the left side of the schematic.) Another much simpler approach would be to run one large conductor to the breakers and use ganged buss bars along each row. Since I want to be able to unplug the panel and remove it completely from the ship I chose the individual small conductor wire approach.

I'm running two #20 wires to and from all circuits that carry more than ten amps. And I'm also using two poles in the switches for the alternator. These things are necessary to avoid exceeding the maximum current specification for the connector and switch contacts, and the wire itself.



Saturday 23 January 2010 – I've finally started connecting wires on the lower panel. I'm working from the panel towards the interface connector rather than come at it from the connector end. I think it will be easier this way. I'll explain why when I get farther along. I've started with wiring that ties the circuit breakers to the switches since it's confined to the back of this panel. Once I get these secured I'll start adding wires that go from the panel to the interface connector – sort of layering the wires that leave the chassis over those that don't. I'll secure the bundle where it exits the back of the chassis but I haven't decided how I want to do that. I'll probably use a Click-Bond adhesive cable tie mount or two. I also want to have enough of a service loop on that cable bundle to allow me to remove it from the pod and still have it connected to the interface chassis. That will be useful during trouble-shooting and debugging.

I cut the wires slightly longer than I need, label the end that's connected with a permanent label and label the loose end with a masking tape label. Then, once I have a logical group like this one I can decide how I want to route them and fan them out at the other end. I'll use lacing cord spot ties to bundle the wires and then cut them to length, add a permanent label, and finally a terminal.

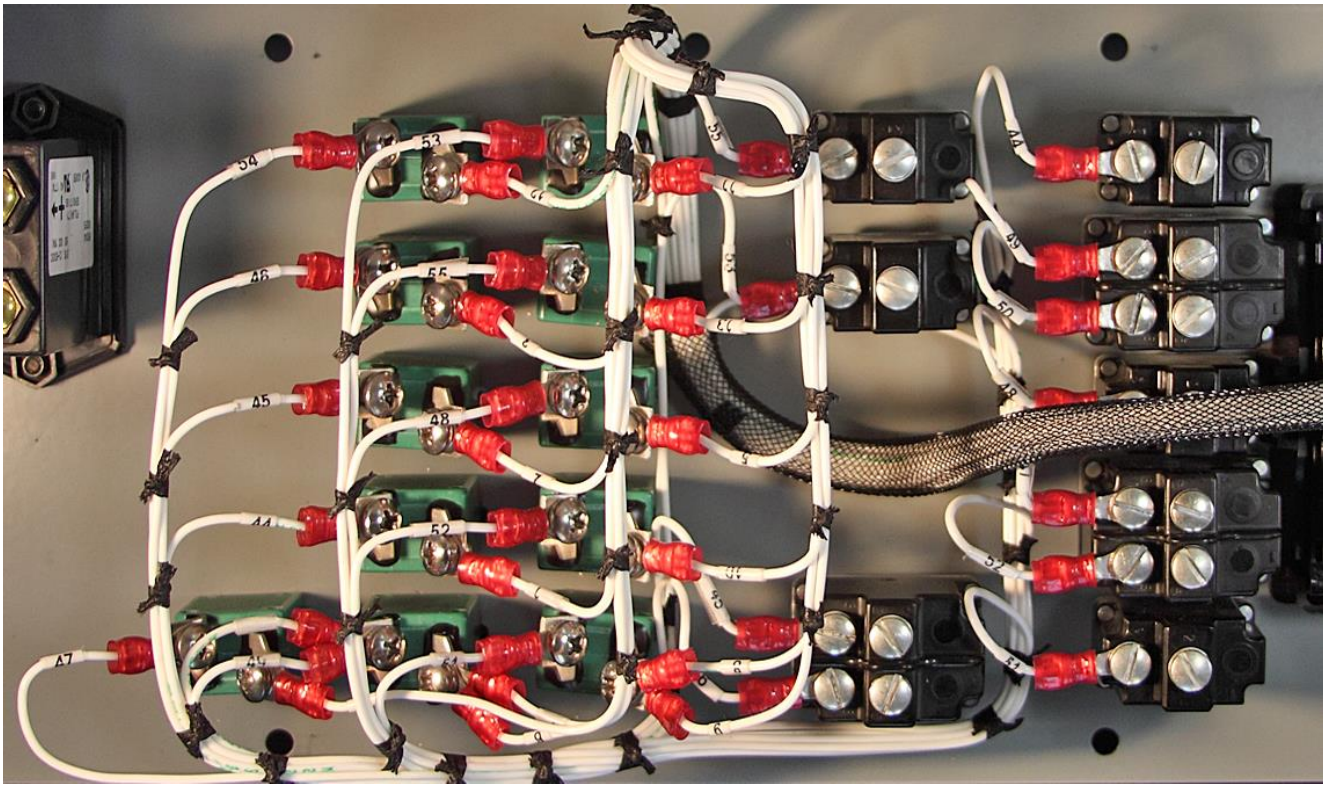


I decided to bring this group of wires down the side of the panel as you see. It includes all of the interconnections between the circuit breakers and the switches. When forming a bundle the idea is to add a spot tie or a tie wrap after every wire entering or exiting the bundle. That way, even without the labels I could disconnect this whole bundle and easily get it back later without scrambling up the order.

Once the wires are bundled and routed to their destination I’ll repeat this process; cut each wire to length, crimp a lug, and label it. The line side of all these circuit breakers will form almost half of the bundle that will go to the interface chassis via connector P6. And yes, there is a line and a load side to these breakers.

I’ll probably end up combining that bundle with this one for a short distance before it breaks out and heads off the chassis. I’ll just cut the spot ties where needed and add the new wires. I’ll also add the wires to the Hobbs running time meter to this main bundle.

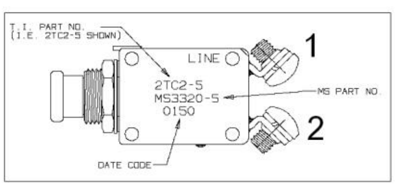
It’s easy to see why you want to label the wires, at least while you’re doing the wiring. They all tend to look alike and you don’t want to have to ohm them out with a Multimeter. Once they’re tidied up like this the labels are less important. (After completing this mini-harness I did ohm each wire out just to be sure.)



Sunday 24 January 2010 – I've added all the circuit breaker input wiring now. It's stacked on top of the previous harness. All of these wires go directly to the interface connector. I've temporarily fed them into some Nylon mesh to get a look. This represents about half of all the wiring that will go to that connector. The rest will consist of switch outputs and the indicators. Everything will meet in that clear space in the middle of the chassis.

While I'm wiring this panel I have two documents that I'm using; the first is the schematic on page 204, and the second is a picture of the back side with all the components labeled. This keeps me from making a mistake when looking at the drawing of the front of the panel and figuring out where that part is from the back.

CONTACT SIZE	WIRE GAUGE
8	8, 10
12	12, 14
16	16, 18, 20
20	20, 22, 24



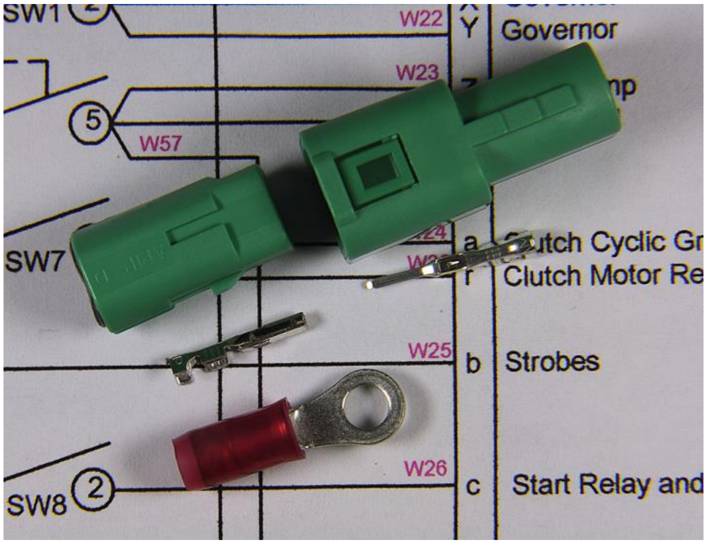
CIRCUIT BREAKER TABLE

CB RATINGS (AMPS)	T.I. PART NUMBER	MS PART NUMBER	VOLTAGE DROP	MINIMUM WIRE GAUGE
1A	2TC2-1	MS3320-1	1.1 V MAX	24
2 A	2TC2-2	MS3320-2	0.7 V MAX	24
2.5A	2TC2-2 1/2	MS3320-2 1/2	0.5 V MAX	24
3A	2TC2-3	MS3320-3	0.4 V MAX	24
4A	2TC2-4	MS3320-4	0.37 V MAX	22
5A	2TC2-5	MS3320-5	0.35 V MAX	22
7.5A	2TC2-7 1/2	MS3320-7 1/2	0.30 V MAX	20
10A	2TC2-10	MS3320-10	0.28 V MAX	18
15A	2TC2-15	MS3320-15	0.25 V MAX	16
20A	2TC2-20	MS3320-20	0.25 V MAX	14
25A	2TC2-25	MS3320-25	0.20 V MAX	12

DRAWN: J. Rivera	SIZE B	N750G	DWG NO. Circuit Breaker & Wire	REV -
ISSUED: 26 September, 2008	SCALE: None		SHEET .	

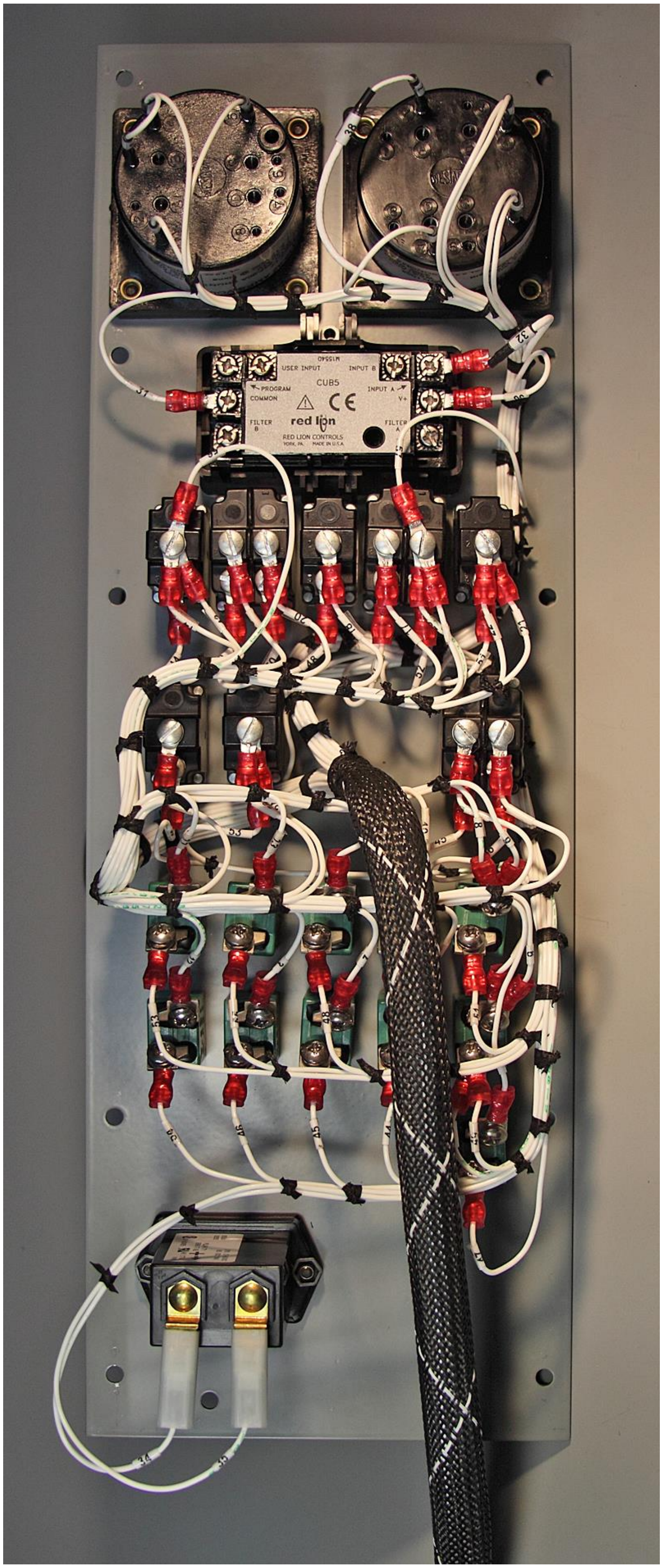
Here's a useful bit of information. It shows the civilian and military part numbers for various sizes of the Klixon circuit breakers I'm using, and the suggested minimum wire size. These particular breakers are temperature compensated so they will continue to function properly at elevated temperatures. The breakers sold by Aircraft Spruce are not rated for extended temperatures and cost just as much.

The military aircraft connectors that I chose to use, since I already had them, use #20 contacts. From the chart at the upper left you can see that I'm limited to 20 AWG wire. From the breaker table you can see that this wire will only take me up to a 7.5 Amp current rating. This is why I'm doubling up on contacts and wires for all circuits using breakers above 10 Amps – I'm fudging slightly from the table when dealing with 10 Amp circuits. If I had this to do over, and didn't have these connectors already, I'd use a line of AMP automotive under-the-hood connectors. They have pins that can handle more current and this would simplify the wiring. Those connectors are designed to take heat, vibration, and water, so they are ideally suited for the Helicycle in my opinion.



Here's an example of this AMP connector family. These particular ones are miniature 7-pin connectors originally designed for motorized door mirrors. They have several gaskets and seals to protect them from water, and best of all they're very inexpensive. I plan to use these everywhere that I have a low-current device that needs to connect to my main harness; strobe lights, sensors, etc.

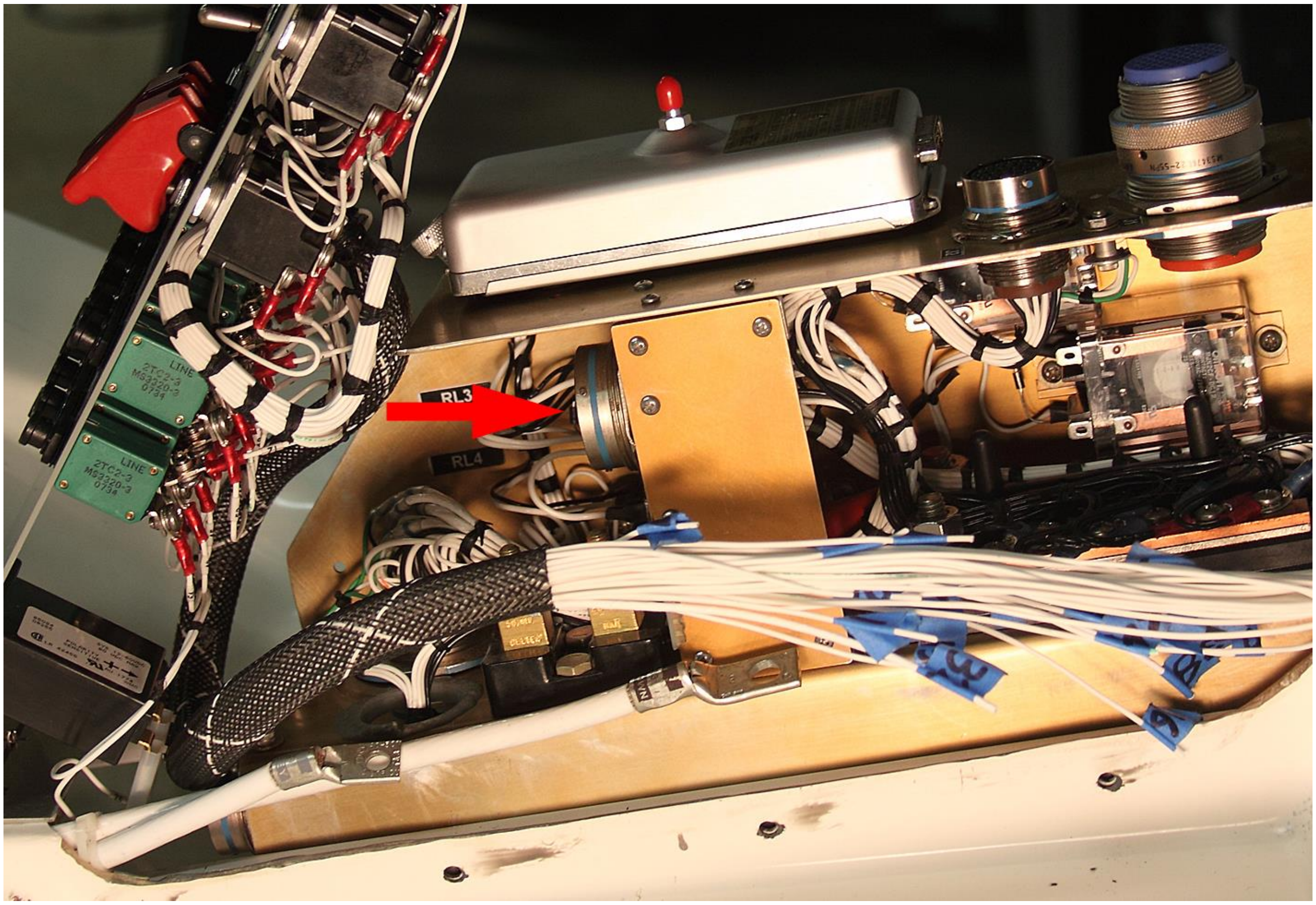
I'm going to try to stick with the MIL/aerospace connectors for anything truly critical. That would include anything required to keep the engine running such as the fuel pump and all of the I/O associated with the engine electronic controller. All of the other sensors such as oil pressure and temperature could fail without killing the engine.



Wednesday 17 January 2010 – The lower instrument panel wiring is complete except for the connector at the end of the cable bundle. I'm going to install a standoff where the bundle comes up out of the wiring and secure the bundle with a cable clamp. I'll center it where the hole would go for a switch if I ever add on in that position. That way I can remove the standoff and install the switch by using the old standoff mounting hole as a pilot for the switch hole.

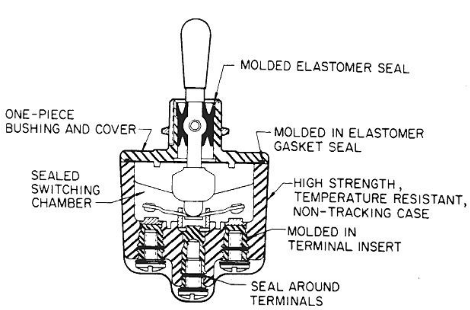
The bundle termination to the connector is straight forward. I'll mark all the wires at the same length as the shortest one and then cut and terminate them one at a time with a pin and insert it into the correct location on the connector. I won't bother to label this end of the wires since they are never intended to be removed again. If the need arises I can always ring them out with a Multimeter.

One thing to remember is to put the backshell on the bundle before terminating all the wires. I've forgotten more than once and then you have to pull every wire back off the connector and start over from scratch. This is especially annoying when each wire was perfectly soldered and covered with a piece of heat shrink tubing. It never seems to go back the second time as well as the first.

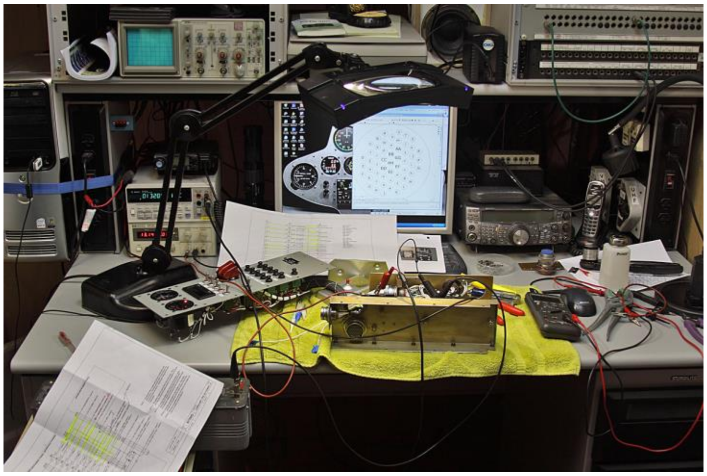


Saturday, 30 January 2010 -- Before I start chopping wires I thought I had better do a fit check to make sure there is no interference problem and I'll actually be able to get to connector J6 (red arrow.) With the cable length cut to the end of the braid I should have enough of a service loop to reach it with the panel removed so I'll get started on that now. (Inside the braid there are no spot ties or tie wraps. That would stiffen the cable and I want it to be as flexible as possible.)

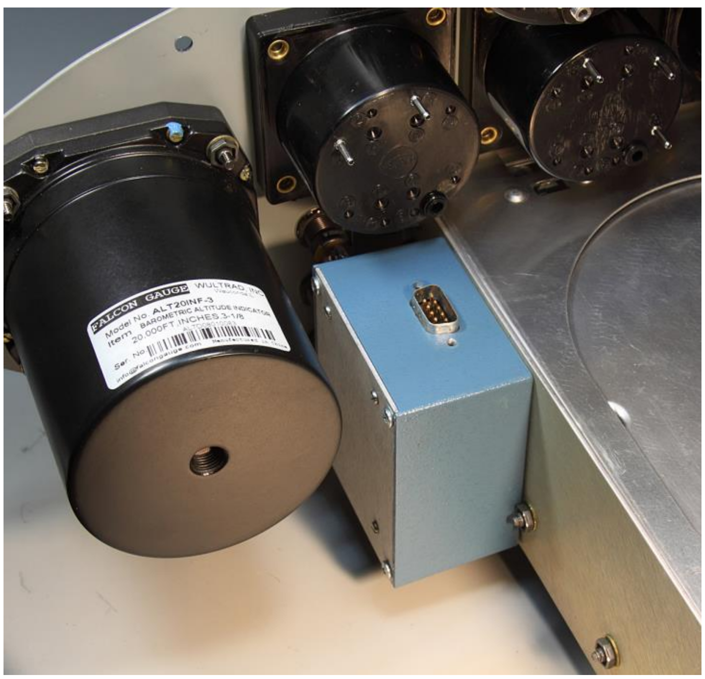
The top panel won't be as easy since I have multiple cables to deal with and there's nothing close to rest the panel on. I'll probably make an access door in the side of the pod. That way I can deal with the connectors while the panel is safely mounted in the pod. It's either that or have long enough service loops in all of the cables so I can place the upper panel on the seat while I deal with the connectors. That would result in a real rat's nest of cable stuffed into the pod, but would offer the ability to run that panel while it's out where I can get at the back. That could be very useful. I'll have to give this more thought…



In my pictures, and in this cutaway view, you can see how these Honeywell TL series switches allow wires to be stacked since the wiper contact is stepped up above the others. These switches are also sealed. As I mentioned before, I've seen them on every commercial and military aircraft I've ever worked on. They're very well made. Like everything else, you get what you pay for.



Now that the connector is wired to my lower panel I'm able to plug it into my interface chassis and start ringing out the wiring. I found that I had two wires reversed so that the current looked like it was charging when there was a load. To dig into the chassis and extract those two pins and swap them was a chore. I've also made some intentional changes to the lower panel that will require some rewiring of the chassis. Overall this wiring project is going as well as can be expected from a prototype. I still have to mount two more attachments to the pod before I can start on the upper panel. I've bonded the attachments to the pod with 3M structural adhesive and rivets. Once the epoxy is cured then I go back in and locate and mount the nut plates. This is a two-day process so I won't get to my upper panel for a while yet.



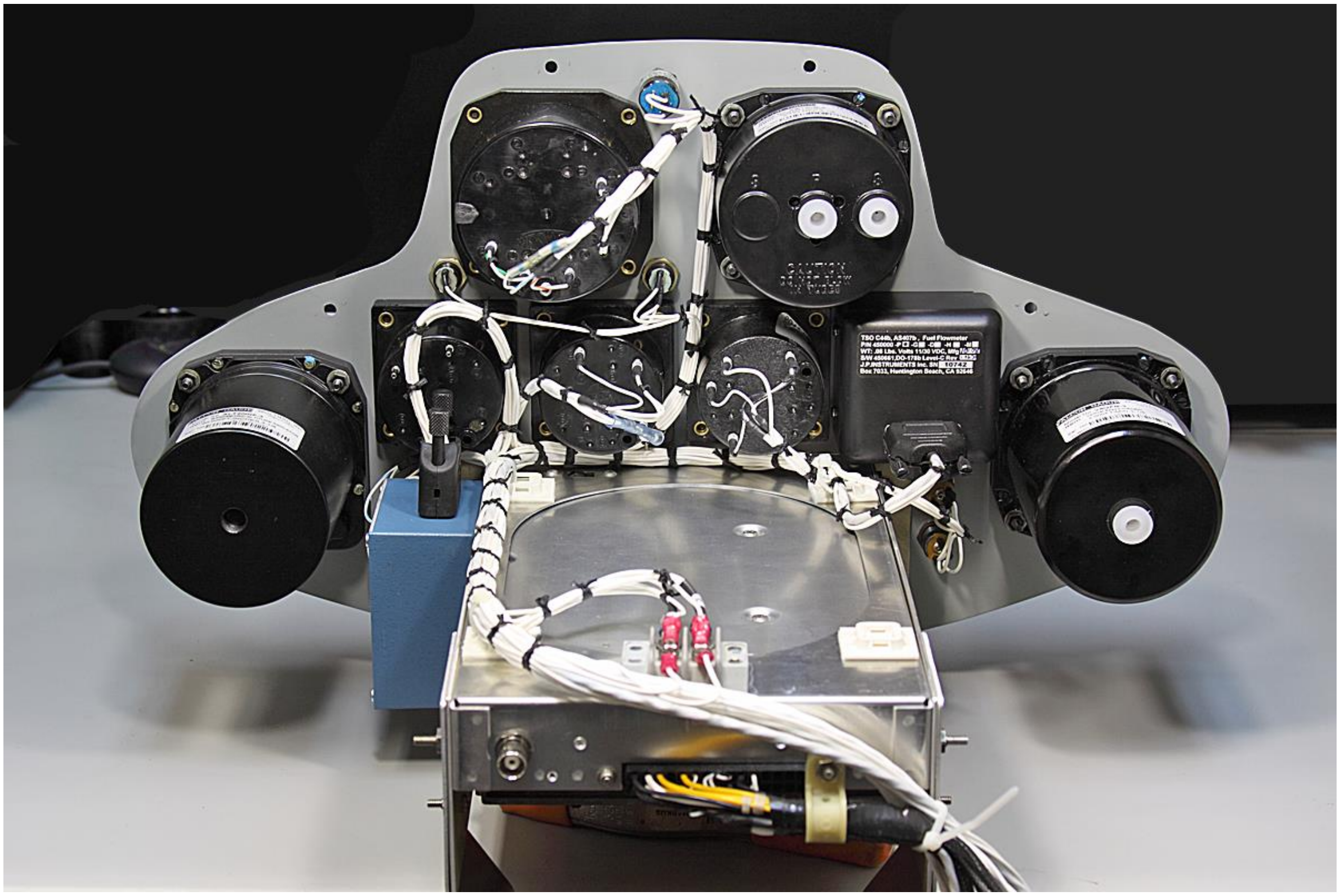
Friday 05 February – I spent about four hours mounting the rotor alarm circuit board in this Pomona case and then mounting the case to the rear of the upper instrument panel. The board is mounted on four standoffs on the lid. Lining up the DB9 connector hole was time consuming. If I had to do this over I would move the box back to allow better access to the three clutch status indicators. I'll have to pull the altimeter out to get to those when I start on the harness.

The next step is to power up the circuit and compare the level of the 6th harmonic of the 20 MHz oscillator to the measurement I took on page 202. That will tell me how effective the box is at shielding against radiated EMI (Electromagnetic interference.) The circuit itself is designed to prevent conducted EMI from propagating through the wiring and out via the connector.

TEST RESULTS: I couldn't detect anything with my spectrum analyzer, even with the antenna a few inches from the case. Using the Icom IC-A210 radio I could hear some minor interference on 120.00 MHz that barely opened the squelch. Some was coming from my PC and some was from unknown sources. Buried down in the noise I could detect a very weak signal from the alarm circuit but I doubt I'll hear anything when I'm using the actual antenna at the back of the ship. There is nothing audible on adjacent channels of 119.975 or 120.025. I'm satisfied.

Here's the fully populated upper instrument panel. The panel is slightly darker than this picture appears but I'm lighting one side with tungsten light and the other with florescent light. The color temperature is all over the map and hard to correct.

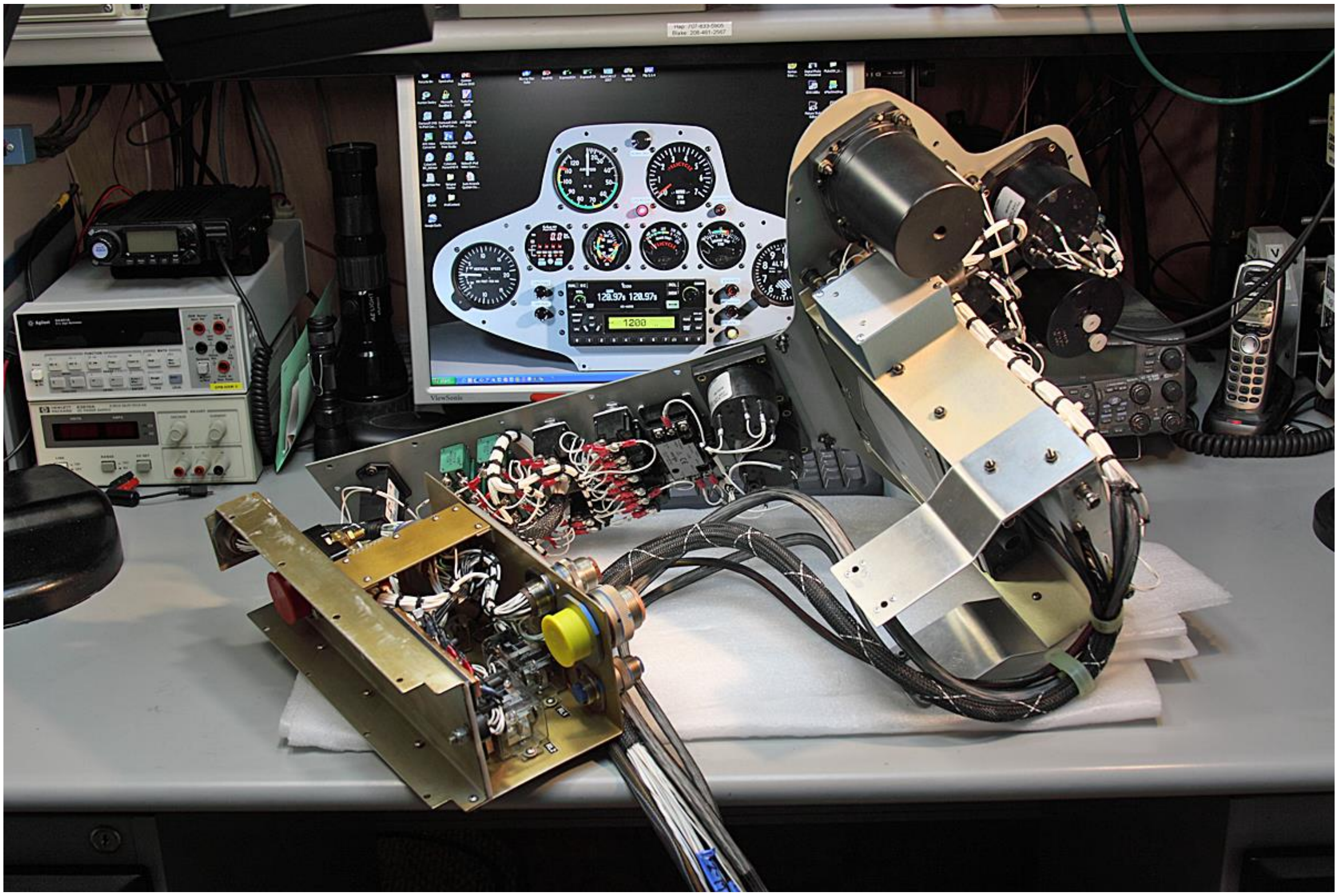
Wiring this panel will be fairly easy compared to the lower panel.



Sunday 14 February, 2010 – Here’s the almost completed upper instrument panel rear view. I’ve brought all the wiring to the back and then next and last step is to decide how I want to strain relieve it and route it down towards the interface chassis. I’ve spent the past week cleaning up my drawings and fixing mistakes that crept into the design and then to the wiring in the lower panel and the interface chassis. I’m fairly sure that I now have a completely functional lower panel and interface chassis. As soon as I connectorize my upper panel wiring I can plug everything together and give it a smoke test. The next item on my agenda is to connect the rotor hall effect sensor and spin it up on my mill. That will allow me to test the interaction between the rotor tach and the rotor alarm (in the blue box on the left side of my radio trays. I still haven’t decided what to use for the red line aural alarm. I don’t want to punch a hole in the lower panel for my Sonalert until I’m completely satisfied that I’ll be happy with the choice. I found the part number for the Robinson R22 alarm. Next time I’m near one I’ll have to see what it looks and sounds like.

To give an idea of the work involved, I spent most of my spare time for the past two weeks creating a new drawing for the interface panel. It’s so complicated that I had to plot it as a D-sized print to be able to use it. Once I had that complete I matched it up to the other drawings and made corrections to those. When the drawings were all corrected I rang out every wire in the interface chassis and the upper panel again and found and corrected several mismatches that crept in over time. I spent all of this weekend wiring the upper panel so I have about twenty hours into that project.

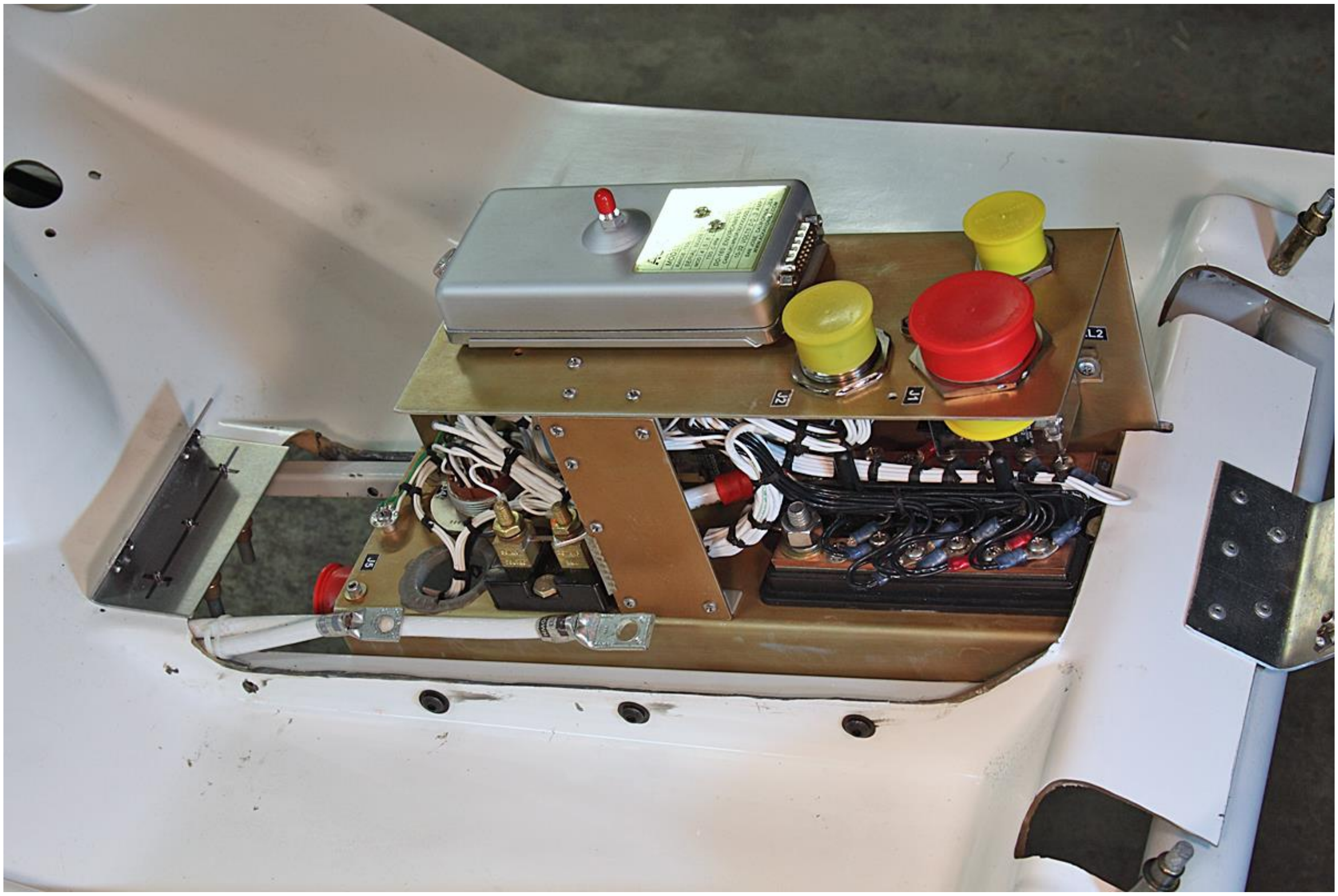
I still have the pitot and static air lines to connect to the flight instruments.



Friday, 19 February 2010 – I'm getting close now… Here are the three major chunks from the rear – the upper and lower instrument panels, and the interface chassis. As the name suggests, everything will connect to the interface chassis via six connectors – the two panels, the cyclic grip, and the helicopter frame including the engine, the lighting, etc. I'll need access to the bottom area to be able to install and remove the connectors and also to allow adjustment of the blind altimeter that sits on top of the interface chassis. I'll have to make an access door on the side of the instrument pod.

This part of the project has been way more work that I anticipated but I think it's coming out nicely and I'm enjoyed every minute of it. I still have to terminate all the cable bundles you see dangling off the side of the bench with connectors and then test everything. I still have a few changes that have cropped up that need to be captured in my schematics and in the actual wiring.

Folks ask me how much the builder has to do and how much is already done by the manufacturer. This is an area where the builder is able to do just about anything they want. Most Helicycle panels look pretty much like this from the front. I've never seen one from the back so I don't know what folks have done there. The basic engine instruments are provided but the flight instruments and the avionics are not. I took the traditional approach and went with so called "steam" gauges as apposed to a "glass" cockpit. I like the look of the older mechanical instruments and they don't fade out in the sun like most LCD panels do. I also opted for Klixon circuit breakers and separate Honeywell switches. Some builders use circuit breaker switches.



Saturday, 20 Feb 2010 – I finished terminating all of the upper instrument panel wiring to connectors. Now I'm ready to move on to the next phase. I moved the interface chassis as far forward as I could to give myself needed room for the lower panel components that need space behind the panel. This will also move my CG forward a tad so I'll need slightly less ballast up front. I'll need access to all of the connectors once the panels are installed in the pod so the next step is to fabricate an access panel. I'll also need to reach the adjustment pots on the blind altimeter. Those adjustments are on the other side but I can always remove the blind altimeter from its mounting tray and pull it out where I can work on it. I'll put the access panel on this side so I can get to J6 which is partially hidden in this picture behind the vertical support piece in the middle of the chassis.

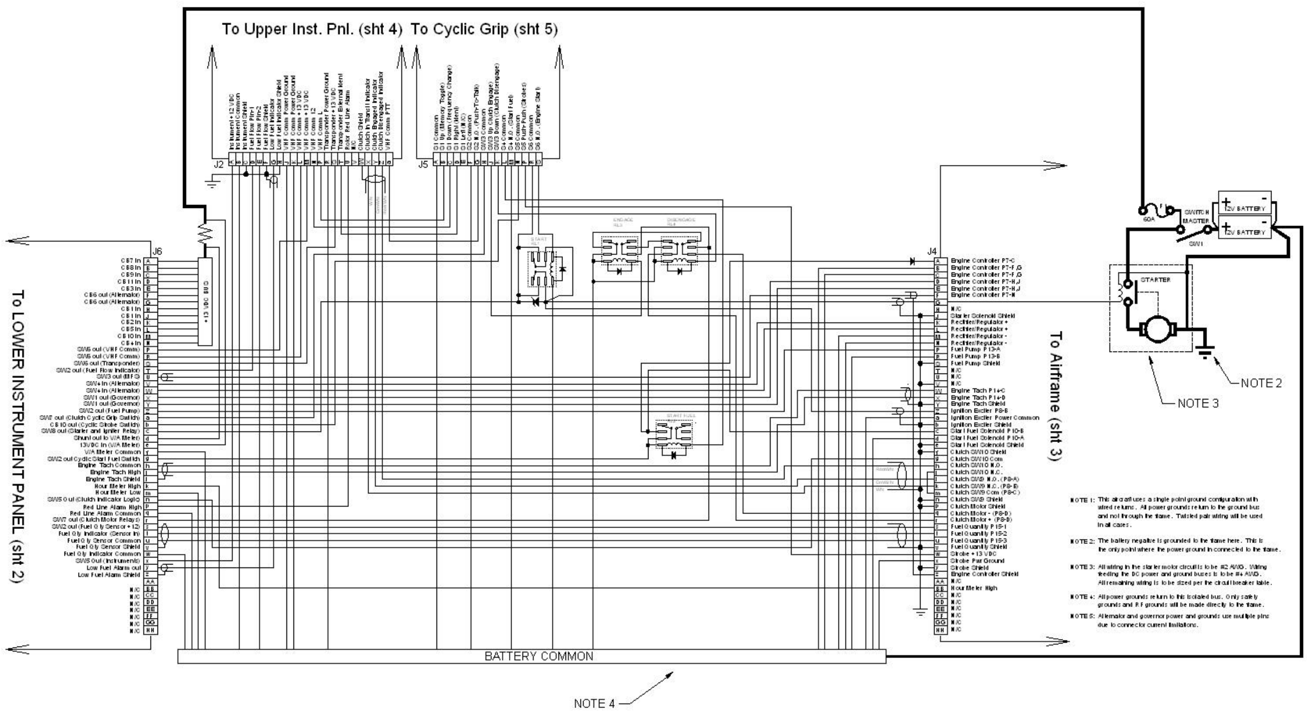
In the foreground you can see the #4 AWG plus and minus lines coming from the battery and master switch. I'll need to extend those a few inches now that I've moved the chassis forward.

Oops! Here's an example of what can happen if you don't plan ahead as well as you should. This is the view looking forward into the pod with the interface chassis in place. There is a structural brace inside the pod that passes right across the area where I thought I'd put the access panel. I may have to rethink this…

I'm still happy with the design, but as I've been getting further and further along I've started to realize that I'm seldom going to need to pull a panel out of the ship and carry it off. That being the case, I can forget the access panel, at least for now, and move on. I think I will make two small access holes to allow adjustment of the blind altimeter and leave it at that.

While I'm wiring the ship I plan to remove the seat pan and install the interface chassis as you see it in the previous picture. Then I'll find a way to connect both panels without installing them in the pod. That way I will have ready access to everything front and back. This will make the wiring go much faster and allow access to everything if I need to debug a problem.

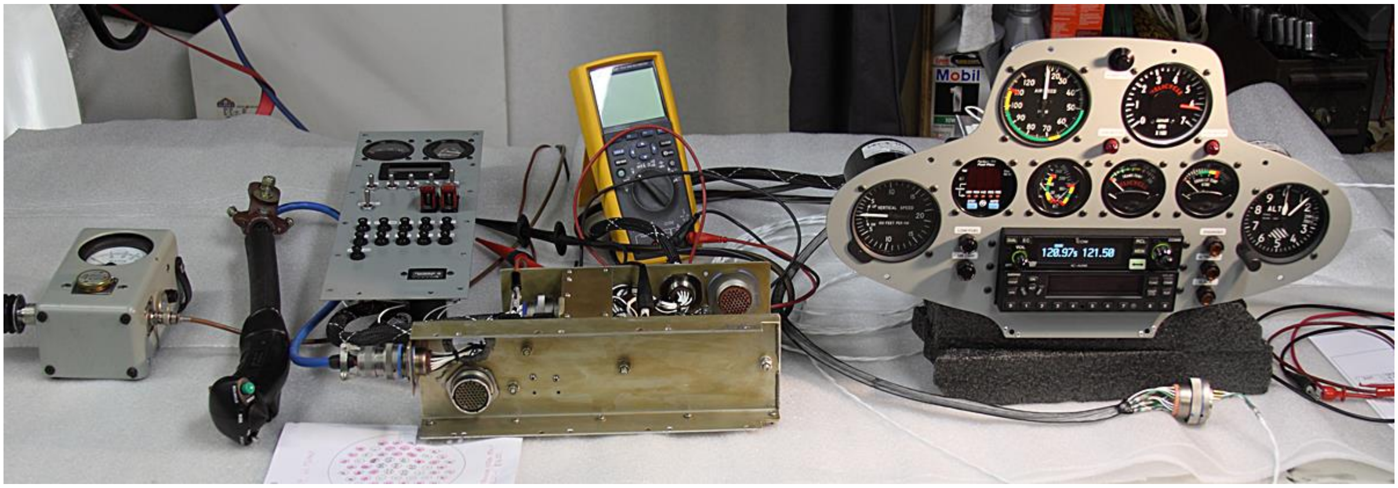
Once the wiring is complete I can install the VHF communication antenna and do preliminary EMI tests to see if any of the panel instruments or indicators reacts to a transmission. As I mentioned, the test that really matters will be later with the engine running.



Here's the schematic of the interface chassis. It mostly acts as a handy place to pass wiring from one place to another but it also contains four relays that are part of the clutch and engine start circuitry.

It also serves as the common ground and power distribution point. As you can see, all the power grounds go to the battery common bus at the bottom of the schematic. This chassis is also the common point for all shield grounds. They do not go to battery common. They go directly to the chassis frame. The frame will be bonded to the aircraft frame when it's final installed. I've tried to shield all signal lines in an effort to minimize EMI (Electo-Magnetic Interference.) As a rule all shields will terminate at this chassis and float at the far end to prevent ground-loops. Shields may be carried through the interface chassis but at their final destination they will normally float. There are probably a few exceptions because I do the same thing at the engine controller chassis. That's the critical circuit. No interference can be allowed to get into that circuit or it could shut down the engine. Interference to anything on the instrument panel will be an annoyance but won't create an emergency. Another huge part of my EMI mitigation plan is the ground plane I have on my antenna. If the antenna system isn't functioning properly all the shielding in the world may not be enough. The only test that counts will be to key the transmitter while the engine is running at a number of frequencies across the aviation band and look for any problems.

OK… here's a rundown of what all the connectors do – The top instrument panel connects to J1, J2, J3, and the blind altimeter. J1 isn't shown on this schematic since all the wiring simply passes through. All of the instruments and most of the indicators connect to the airframe through J1. All the power and grounds from the lower panel passes through J2, along with lines to the clutch status switches. All of the VHF transceiver audio passes through J3. J4 is on the bottom at the left and points downward. All connections to the airframe from the lower panel or the interface chassis pass through there. J5 is the interface to the cyclic grip. It's the connector with the red cap at the very bottom left of the picture. J6 is the last connector and connects everything from the lower panel.

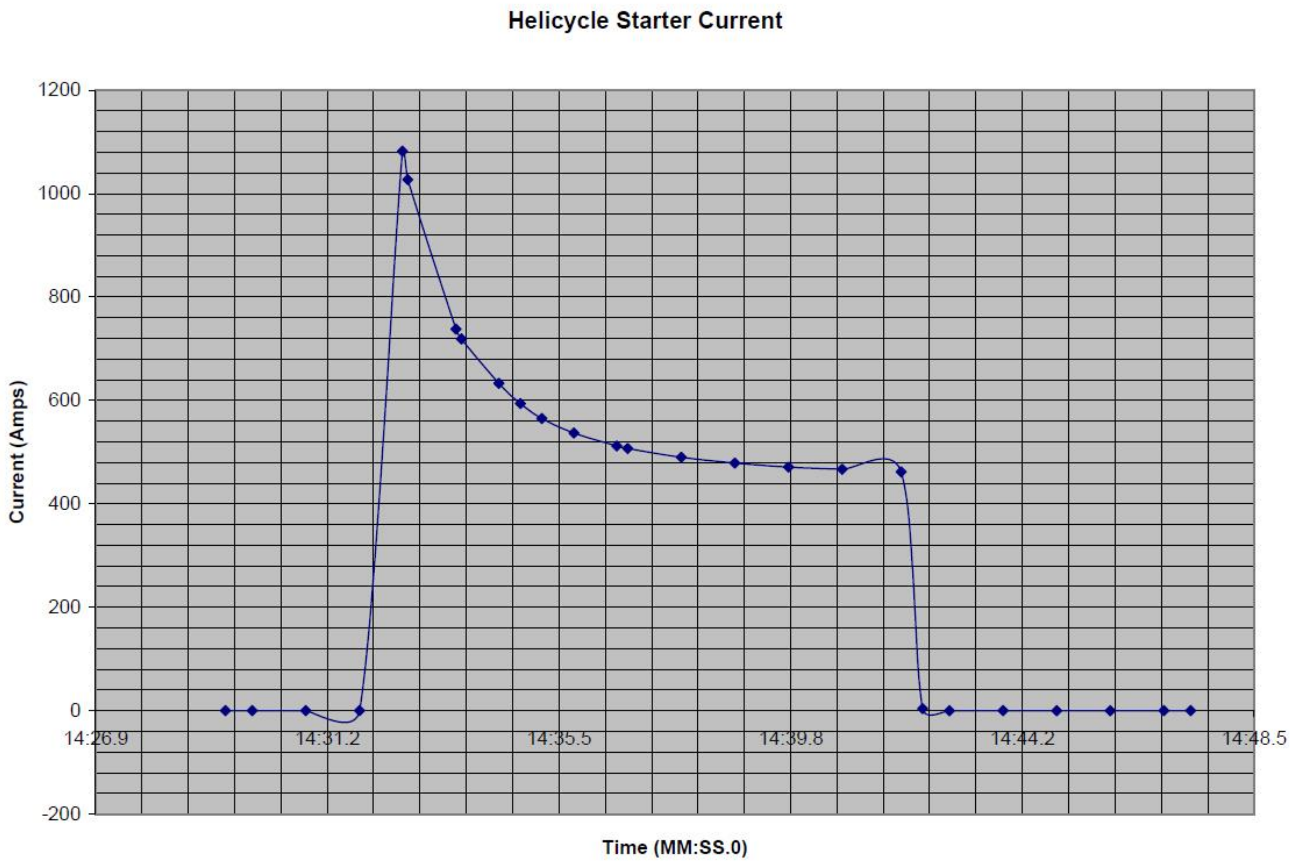


I moved everything to a large table so I have room to work. I have the cyclic grip switches connected and the VHF transceiver connected to a wattmeter and 50 ohm termination so I can transmit to check for EMI. As I worked my way through the wiring I found a few more wiring errors but nothing major. With everything set up in my garage I am now able to connect the rotor tachometer to a Hall Effect sensor and drive it with my mill. I wanted to see if there was any interaction between the rotor alarm and the tachometer (there isn't) and also check for any EMI problems by keying up the transmitter (there are none.)

The three pictures above are a graphic example of why I wanted to design a rotor RPM alarm.

- The left picture shows a rotor RPM of less than 610, setting off the low rotor RPM alarm (bottom of green band)
- The middle picture is somewhere between 610 and 620 RPM and no alarm is set (inside the green band.)
- The picture to the right is an RPM above 620 and setting off the high rotor RPM alarm (top of green band)
- When the RPM exceeds 635 RPM the high rotor indicator is still lit and a second aural alarm sounds (red line)

Notice how small the difference is between the three speeds on the tachometer. I doubt anyone is able to really keep an eye on the RPM using this particular indicator. It looks nice but I think it's fairly useless. If I get the time I'm going to replace this with a digital expanded scale meter using the same basic circuit already proven in the alarm.

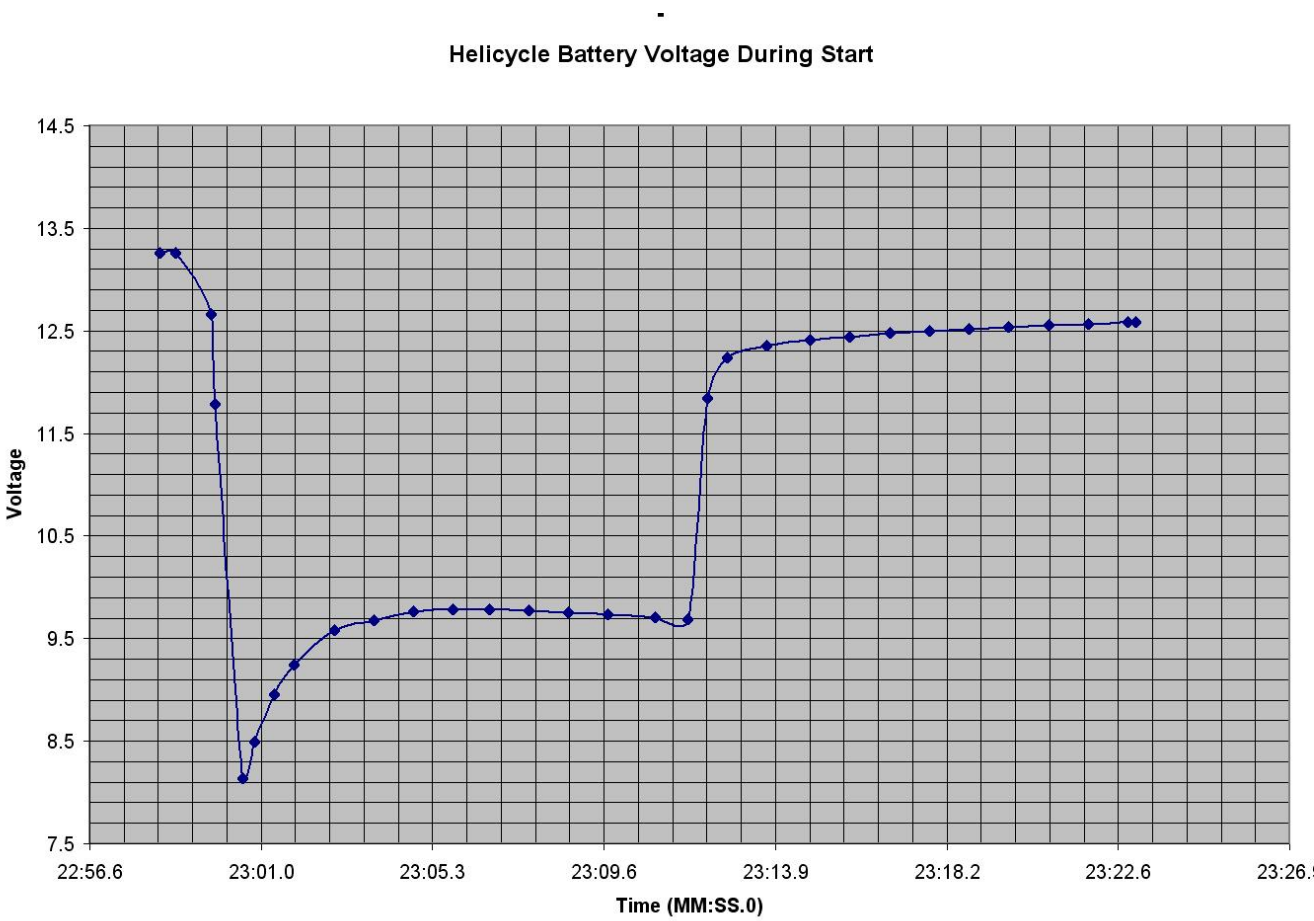


Monday, March 01, 2010 -- I installed the last remaining oil line yesterday so the engine is now sealed up and full of oil. I also have enough of the electrical system connected to my instrument panel to finally allow me to turn over the starter and measure the current. Per Blake's suggestion, I limited myself to less than ten seconds.

I used a Fluke i1010 AC/DC current clamp and a Fluke 287 multimeter. The 287 is able to capture data, graph it, and download it to the PC. Here are the results of a start sequence (no fuel – just turning the engine on the starter.)

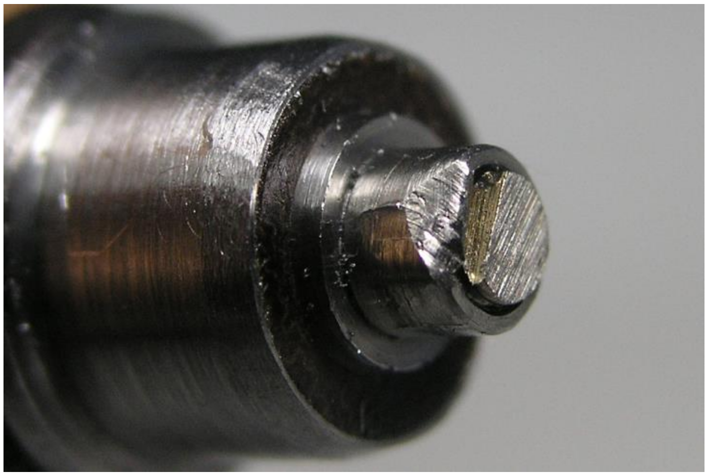
As you can see, the initial current is an amazing 1081 Amps, tapering down to around 450 Amps within about four seconds. Actually this is about what I expected. Electric motors draw a lot of current when they first start. It's called "locked rotor current".

The power source is two Odyssey 860 batteries in parallel. The starter is connected directly to the two batteries using #2 welding cable. Since the batteries are directly above the started, the lengths are short and the resistance is extremely low. During this test my clutch was not completely disengaged so I will repeat it again and also monitor battery terminal voltage.



Tuesday 02 March – This is a battery voltage plot during an engine start run (without fuel or ignition and clutch fully disengaged.) The plot starts just before the starter was engaged, showing the voltage being drawn down to 7.45 volts during the initial current surge to get the starter turning, then leveling off at about 9.8 volts for the duration of the start. Once the starter was disengaged the battery voltage jumped to 12.24 volts and then slowly increased to 12.58 volts where the recording was terminated. The time scale at the bottom of the plot is minutes/seconds/tenths of seconds.

It's easy to see why people are having trouble with their instruments malfunctioning during a start. Obviously this is not an adequate voltage supply for sensitive avionics and instrumentation and especially the engine controller. (Equipment designed to operate at 13.5 volts normally will not function reliably below about 11 volts.)



I'm checking my wiring as I install it. When I hooked up the transmission chip detector to the instrument panel the chip light came on. At first I thought I had a short, but the wiring was ok and the detector was telling me the truth. When I drained my transmission and pulled the detector it was shorted with metallic fuzz. It looks like the fuzz came from the tip itself (see picture above) but this makes no sense at all since this magnetic tip is enclosed inside the housing (see page 67 for a picture of the complete part.) How could it get ground up like this when I haven't even run the engine?? I hate the idea of pulling the fixed part of the unit since it's almost inaccessible now that the fuel tanks and the clutch are installed.

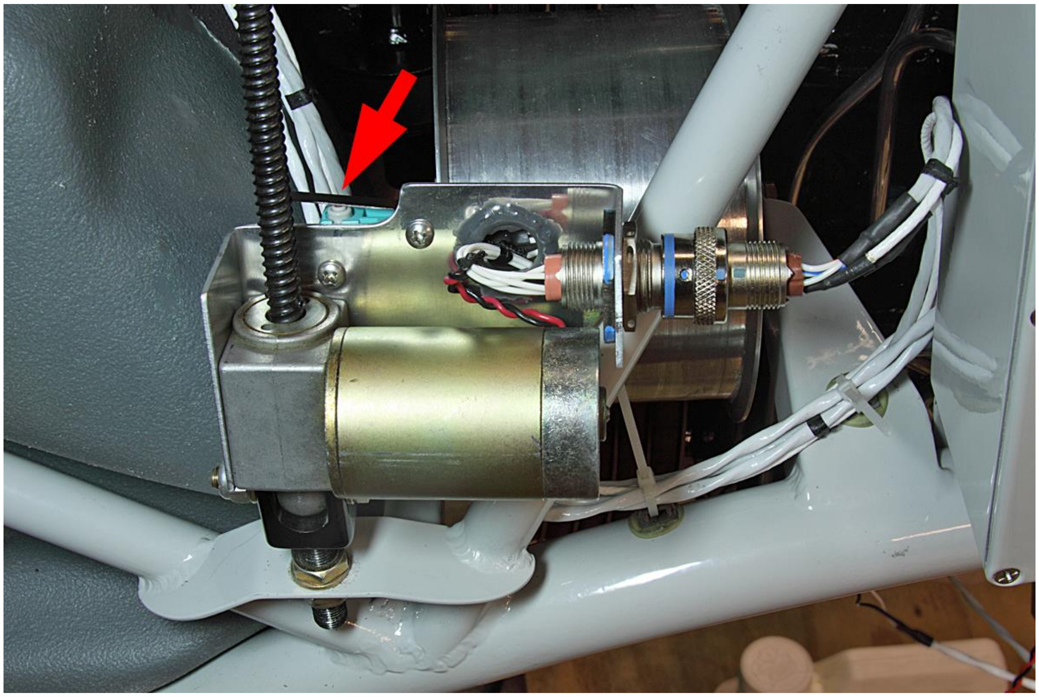
I'm using the detector that was recommended by Blake at Eagle R&D (part number 207-1 from Aviation Development Corp. in Seattle.) I was told that they sell lots of these to Helicycle builders. This is very strange…

08 March 2010 – I've spoken with Blake at Eagle R&D and received a lot of good suggestions from the builders group. Here's my thinking so far:

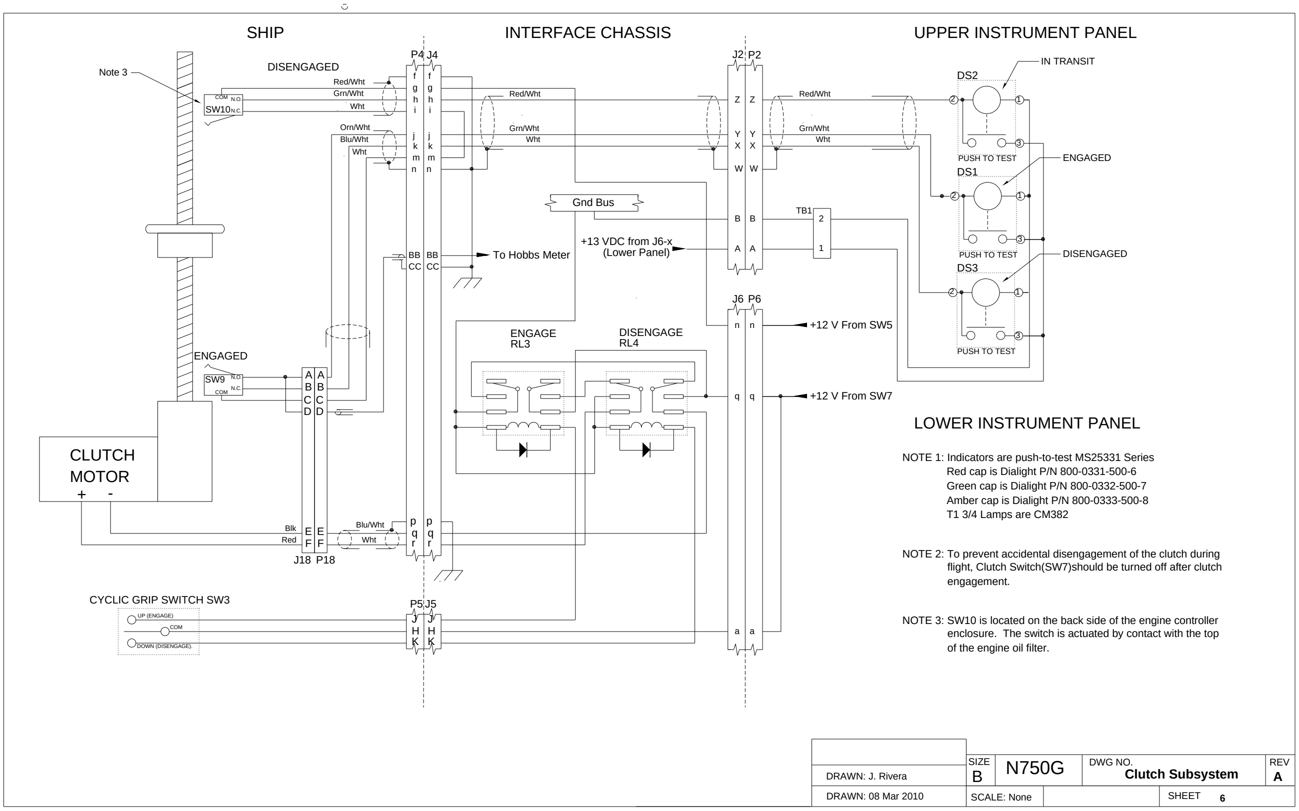
1) The transmission oil viscosity is too high for particles to "jump" from the bottom inside surface of the transmission to the tip.
2) I haven't exercised the transmission enough to circulate the oil so particles suspended in the oil are not the source.
3) There was/is no interference between the chip detector and the transmission internal parts or I would have noticed long ago. I've rotated the main shaft through many rotations by hand and I've never felt the slightest drag or grinding. It's smooth as glass. I spun up the engine one time with the clutch not fully disengaged and the transmission was rotated by the loose belts. If it had a clearance problem with the chip detector I think it would have stopped turning and the belts would have simply slipped.
4) I'm fairly sure that I ohms the detector out before I installed it, but it's been over a year and it could have been shorted with chips when I installed it.
5) Draining the oil will not show any chips since it comes out as slowly as honey.

Possible next steps:
1) Buy a flexible bore scope (in the mail!), pull the chip detector housing and take a look
2) Pull the housing and attempt to sweep the area around the access hole with a clean white cloth so see if it picks up any particles
3) Use a magnet to do the same thing
4) Exercise the transmission for an hour or two using a temporary motor/pulley arrangement and then pull the filter, drain the oil, etc.

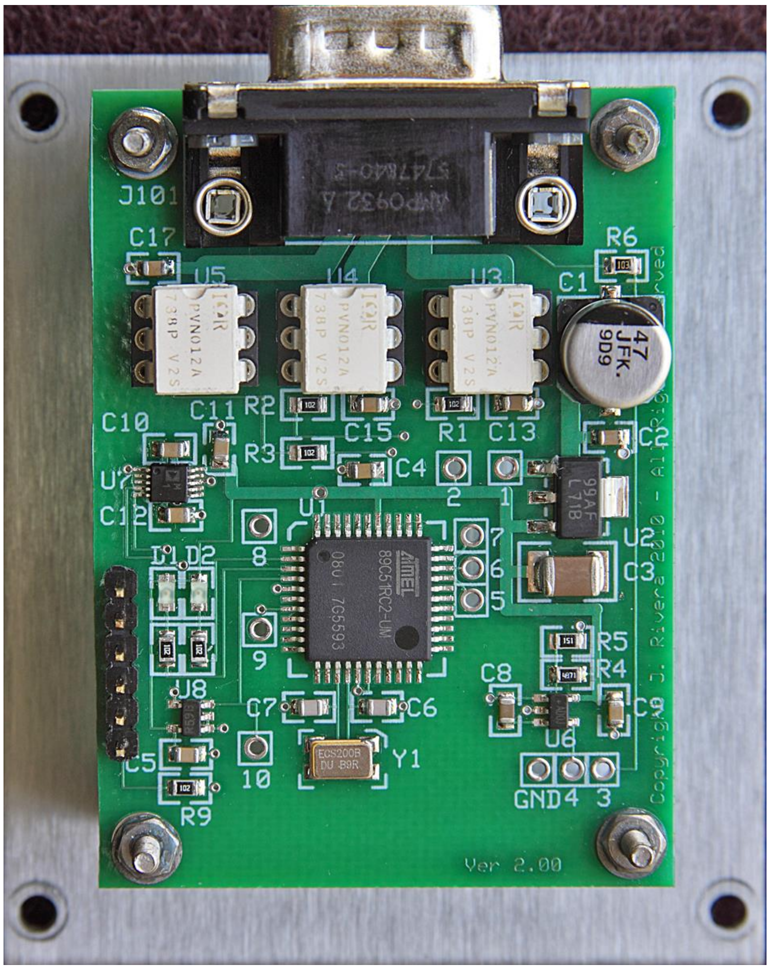
I have plenty of time to plan my next move…



I'm currently working on my wiring. The instrument panels and the interface chassis are complete. Yesterday I fabricated a new bracket for the clutch jackscrew assembly. My previous design ran the connector (P18 in the drawing below) out the back and it was too close to the pulley. I like this one much better. It's made from 0.060" 6061-T6. I laid it out using AutoCAD and then printed it 1:1. I use the print as a template to do my cutting and drilling. It's fast and works great. I decided to hit it with my buffing wheel and polish it so I wouldn't have to wait for paint to dry. The red arrow points to the limit switch (SW9) that is activated when the clutch is fully engaged. It lights a light on my upper panel.



Here's my schematic. The switch I'm pointing to is labeled SW9, "Engaged". Here's how it works: The center-off toggle switch on the cyclic grip controls relays RL3 and 4. They send 12 volts at the correct polarity to the motor to move it in the direction I want. I have three indicator lights on my upper panel – engaged, in transit, and disengaged. The two limit switches, SW9 and SW10 handle the logic for the lights. The power to the motor is supplied by a red guarded switch (SW7) that I will turn off during flight to prevent inadvertent movement of the clutch. There are a lot of switches on the cyclic grip and I don't want to hit the wrong one in flight. I also will kill power to the starter motor in the same way. Lastly, SW9 supplies power to the Hobbs running time meter. That way the meter will log hours when the engine was up to speed and supplying power to the transmission.

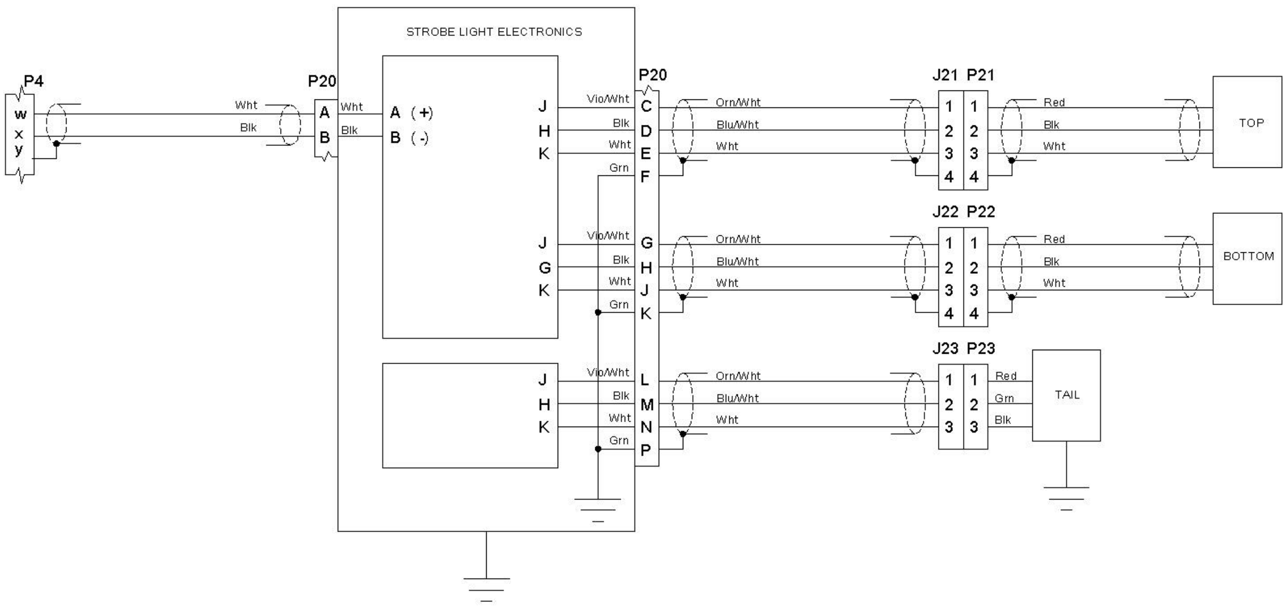


Sunday 14 March – The last version of my rotor alarm worked like a champ but it was very unforgiving of power glitches. As you can see on pages 219 and 220, engaging the starter causes a massive disruption to the DC bus. I believe I have a cure for that but I'm getting ahead of myself. This particular circuit was so sensitive that it did a reset every time I turned on the avionics. This was caused by my choice of a 5 volt regulator that wasn't quite up to the environment that it faced.

This version uses a regulator and input and output filtering that is designed for automotive under-the-hood applications. It protects itself and the circuitry against reverse battery connections, and up to +60V/−50V load dump transients. It should continue to function with an input voltage as low as six volts.

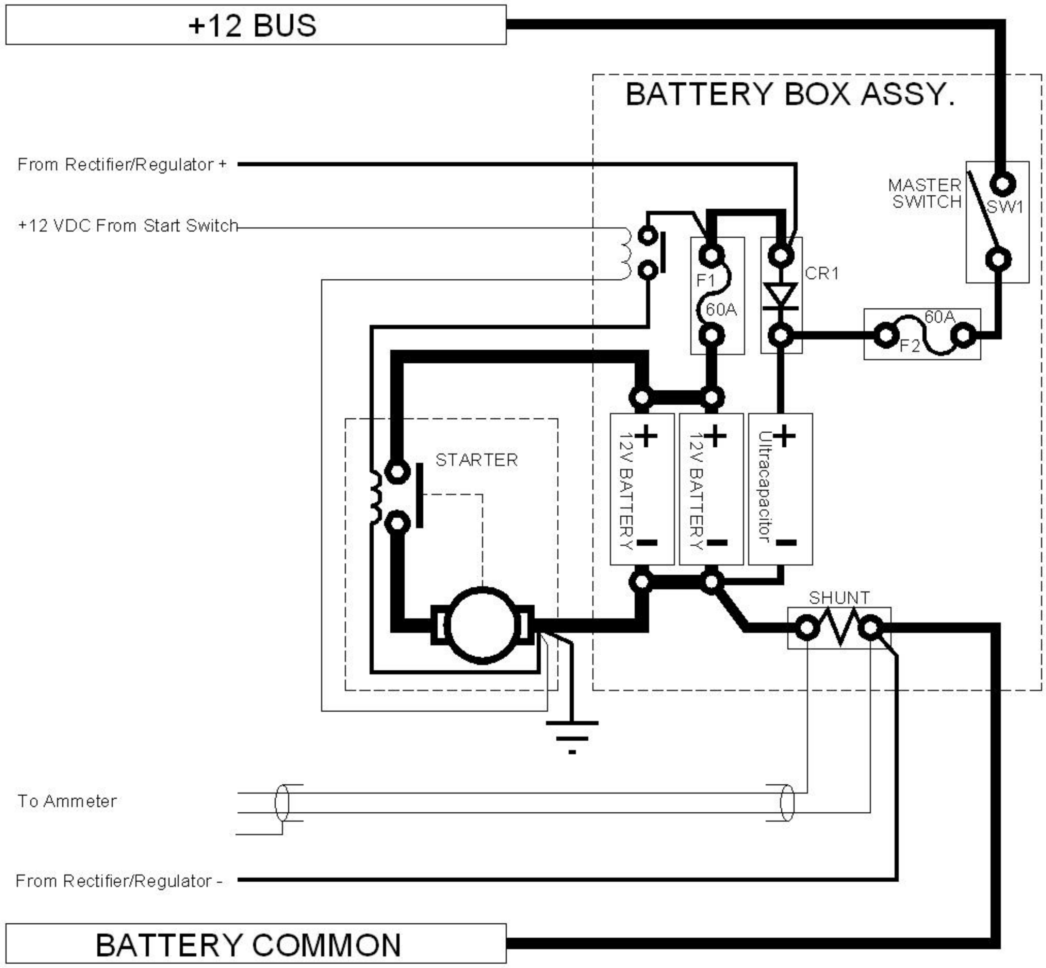
It won't be bothered by the avionics being switched on any more, but the real test will be the starter. Protecting against that huge transient will take the help of an ultracapacitor. If this alarm circuit sails past the starter engaging without resetting itself I'll know both problems have been completely solved. This little circuit will be my canary in the coal mine.

The circuit board measures 1.5" x 2.8". It takes me about four hours to assemble these boards using a stereo microscope. If I get around to selling these I'll farm that job out to an assembly house. This is my seventh circuit board version. At $91.41 per order it's getting expensive. I believe this will be my final design. The next step is flight testing in a Helicycle. I don't anticipate any problems.



I thought I'd stick this schematic of my strobe lighting here since it's a simple example of shielding do's and don'ts. The strobe produces some very fast rise-time high voltage pulses that can cause radiated and conducted EMI. I'm going to see if I can keep all the clicks out of my audio by taking some standard shielding precautions. Here's a list:

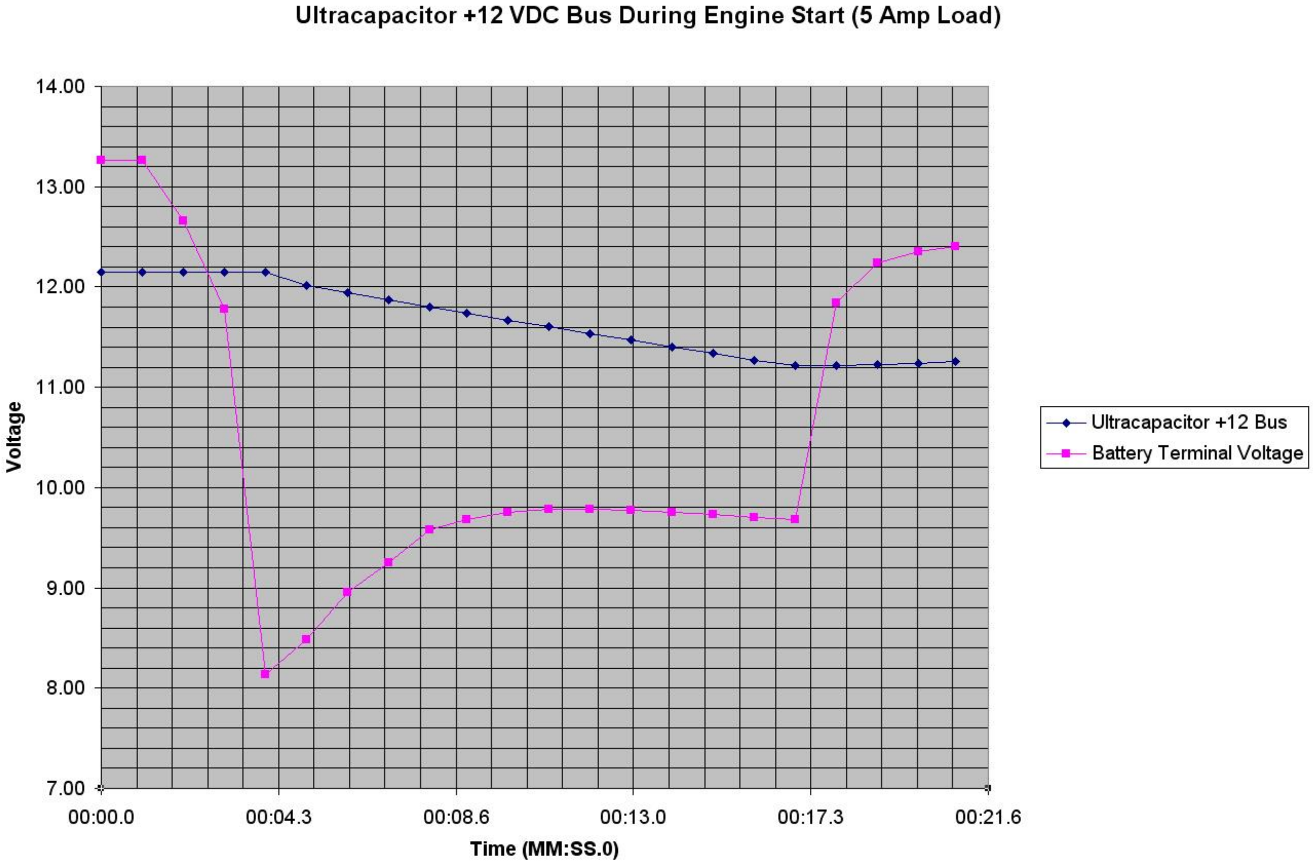
1) Carry the shields all the way from end to end. See connectors P20, J21/P21 and J22/P2.
2) Only ground the shield at one end – usually as the source. I'm grounding them at the electronics chassis (P20, pins F, K, and P.
3) At the far end let the shield float. Insulate using heat shrink tubing so those little strands don't touch anything. This prevents "ground loops". A ground loop creates a circular path via the shield and then back through the helicopter frame or other sneak path. This can cause noise to be coupled into the shielded wiring.
4) The electronics chassis is my common shielding point with one exception. This chassis should be bonded to the frame in most cases. Sometimes it might work best if the chassis was insulated from the frame. Shielding is as much as art as a science, so some experimentation is often required to get the best results.
5) My one exception to #4 is the input to P20, pins A and B. That cable's shield is grounded at the interface chassis which is my main shield grounding point. Since it's grounded there I'm floating it at the strobe chassis.
6) Keep all the noisy cables as far away from sensitive cables as you can. I'll try to run my output cables on the far side of the frame from my main wiring bundle. The same goes for my VHF transceiver and the transponder antenna cables. You don't want those bundles with your other cabling such as the fuel quantity, etc. Cables in close proximity couple energy. The closer they are, and the longer they are running parallel to each other, the worse it is.
7) The reason #6 is true is that cable braided shields are only about 70% effective.
8) Always use STP cabling (Shielded Twisted Pair) for signals that are differential (they have a + and a -.) The twists in the cable cause any noise that is coupled into the wires to cancel itself out every time a twist comes along. Noise is defined as any unwanted signal.



Sunday 28 March – I've deleted several previous descriptions of this circuit which changed during the development and debugging effort. This is the final version.

The Problem – When you hit the starter it draws so much current that the battery voltage drops down briefly to about seven and a half volts and then raises to around nine and a half volts until you let off the starter. The electronics that you need to run the engine don't like that. The engine RPM indicator may reset, the igniter may stop firing, the engine governor could be acting oddly… It's not a good environment for electronic equipment.

Here's my solution. The batteries charge a device called an "ultracapacitor" through F1 and power diode CR1. The ultracapacitor supplies power to the electronics via F2 and master switch SW1. When the battery takes a dump during a start (see graph on next page) the ultracapacitor is isolated from the batteries by the diode so it doesn't get pulled down with them. It then supplies power to the electronics bus from its stored energy until the battery voltage comes back up after the starter is switched off. Once the battery voltage exceeds the ultracapacitor voltage it's recharged via the diode (you can see that starting to happen at time 00:17.3 on the graph that follows.) There's a bit more to it than this, but that's the general idea…

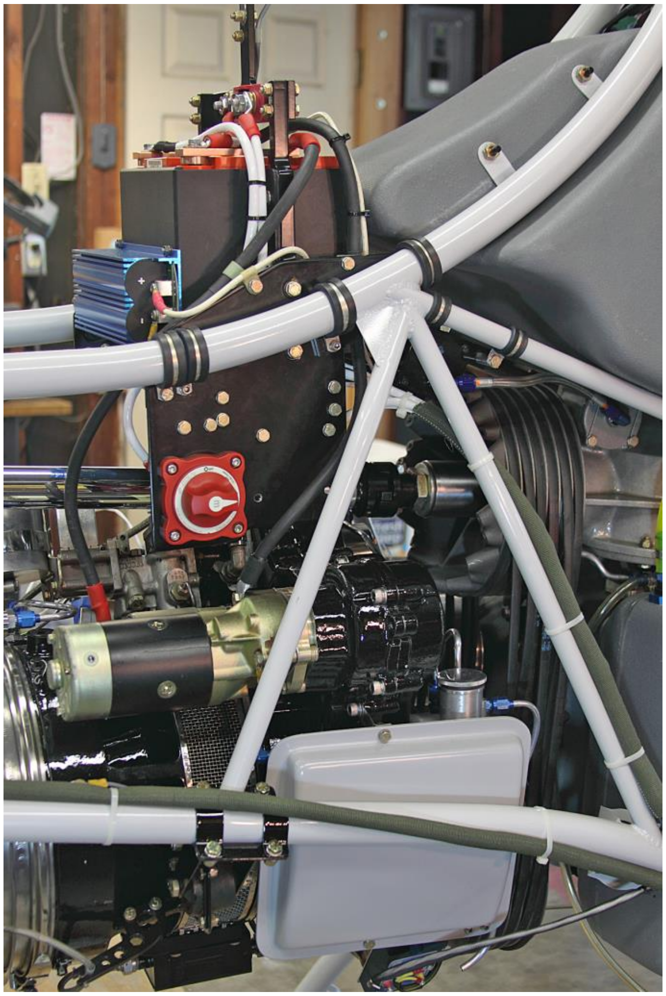


The pink trace shows the battery terminal voltage during an approximately ten second starter engagement. I show the current on page 219. It peaked at 1081 Amps and then settled at around 450 Amps after four seconds. You can see that the battery terminal voltage dropped like a rock when that huge surge hit and then, as the current came down, climbed to about 9.5 volts until the starter was shut down. It then jumped back up to about 12.4 volts. During my test the +12 bus stayed at or above 11.25 volts and there were no glitches. The total load for this test was approximated five Amps. That should account for the igniter, the engine governor, the fuel pump, and the instruments. Best of all, my "canary in the coal mine" rotor RPM alarm didn't reset! I'm extremely happy with this outcome.

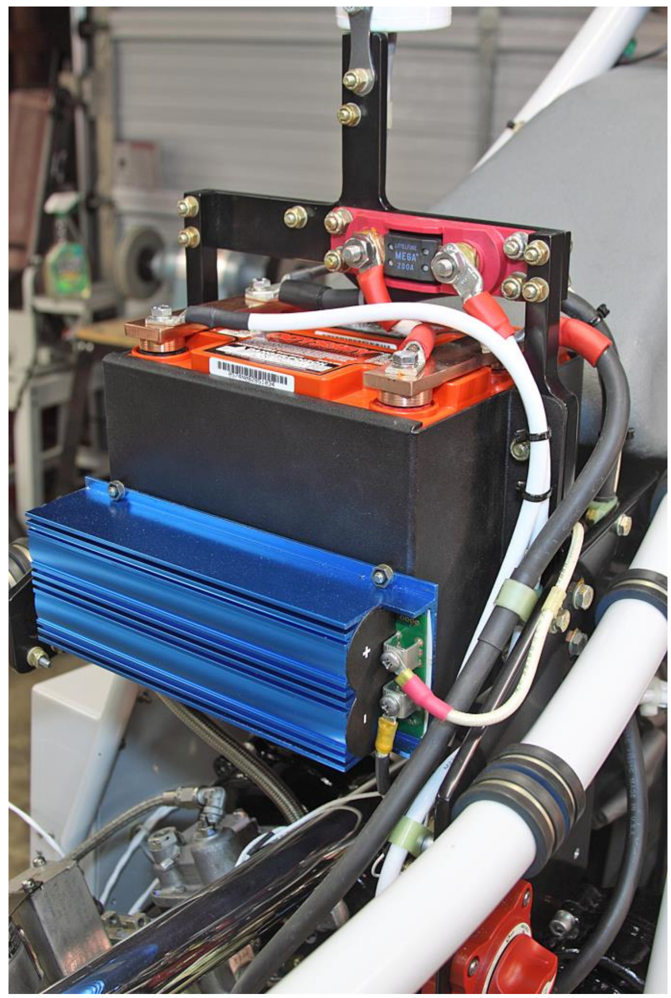
Some people have criticized my approach and claim to have already tried this with huge capacitors hooked to their instruments. Let's define "huge". The capacitor I'm using is fifty eight farads. That's fifty eight mission microfarads. That's my definition of huge.

Why not another battery? Ultracapacitors are small and light and aren't filled with acid. They can be charged at a very high rate, unlike a battery, and they can withstand hundreds of thousands of cycles without any maintenance. This is an ideal application for this component.

A word of warning – If you plan to try this be very careful and make sure you understand the difference between a regular capacitor and an ultracapacitor. The internal resistance of my ultracapacitor is about .008 ohms. That means that it can source or draw a lot of current. This is especially critical when charging one that has discharged. Before connecting the ultracapacitor to the batteries you should slowly charge the ultracapacitor to match the battery voltage. This will prevent excessively high charging currents which could damage components in the electrical path. I use a 50-watt 12-volt camera light. Place it in series with the ultracapacitor and wait until the light is completely extinguished.

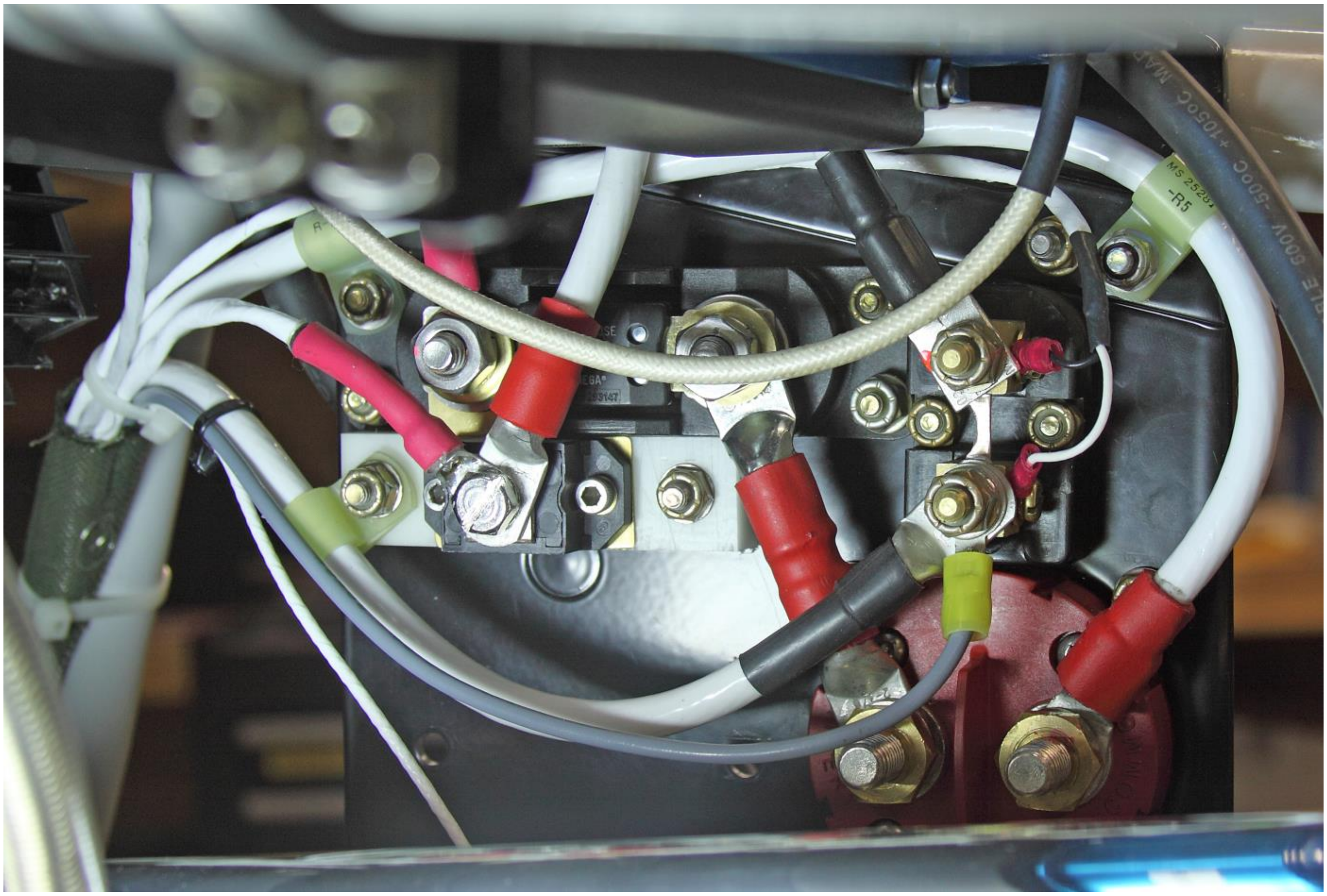


Here’s the installation. The ultracapacitor is the blue device on the back of the battery box. I’ve mounted everything directly above the starter so the #2 AWG welding cables are very short. The two batteries are tied together with quarter-inch by one-inch copper bars. I’ve paid very close attention to insuring that there are no sharp edges or other areas where these cables could short. If they ever did it would be extremely ugly, especially since the fuel tanks are right in front.



Here you can see the bus bars that I made. I turned some round pieces from the quarter-inch stock to get the bars above the plastic battery case. I didn’t quite make it so I milled relief on the bottom side of the bars. I also replaced the stock metric battery bolts with longer ones to account for the added half-inch thickness of the bus bars.

Everything is clamped or tied down to prevent cables rubbing against sharp edges. The 60 amp fuse above the battery box (F1) will provide protection against shorts to the smaller cables but there is no protection on the starter wiring. I’ve taken every precaution to insure that the hot cable doesn’t short to the return. If it shorted to the frame the ground wire from the starter motor case to the frame would act as a fuse.



This is the view looking at the inside of the right battery box panel. Again, I've tried to tie everything down using cable clamps[1] and tie wraps. I have a few odds and ends left to tidy up so there are still a few loose wires. I've used #4 AWG cable to run power from here to the instrument panel via the interface chassis. Even thought the total current is low compared to the size of this cable, I wanted to cut down on what are called 'IR' losses. It comes from Ohm's law; E=I x R. The voltage drop in the circuit equals the current times the total resistance of everything in the circuit including the ground return. Since heavy cables like this can draw tremendous current when shorted I've fused them at the source (here at the battery box.)

Circuit description – There are several current loops going on in this circuit. I'll take them one at a time:

High Current Starter: The starter circuit consists of the two batteries, the bus bars connecting them together, the interconnecting cables, and the starter solenoid. There is no circuit protection here so a short would be devastating. Also, this current path bypasses the ammeter shunt.

Medium Current Starter Control: The starter solenoid itself is a hog, consuming about 17 amps. I control the solenoid with a single pole. Single throw power relay shown next to F1 on the schematic. The path for this current is from the battery, through F1, the contacts of the power relay, then the starter solenoid coil, then internally to the starter motor housing, and back to battery common. It also bypasses the shunt.

[1] I love these MS25281 cable clamps. They're very high quality but very hard to find for some reason.

Alternator Rectifier/Regulator: This path is through F1 to the batteries and the return is through the shunt.

The Ultracapacitor: The ultracapacitor is charged via F1 and CR1 and the return is to battery common bypassing the shunt. I could have included the shunt but the peak currents in that loop might have caused damage to the shunt or the ammeter.

Ship Electronics: The electronics are ultimately supplied from the batteries via F1 and CR1 and then through F2 and the master, and the return is back through the shunt. As mentioned, during large momentary drops in battery voltage the ultracapacitor supplies power to the electronics.

The reason I've placed the shunt in the ground return path is to capture all the combined currents; the input from the alternator and the various loads from the electronics. The ground return is the one common place where I can measure them all.

On my ship all ground returns go to the bus in the interface chassis and from there back to battery minus. The frame is bonded to this return at the starter but no current should pass so the bond wire is small[2]. The only current that should pass through this sneak path is the transmission chip detector. If it shorts it pulls the hot wire to the transmission case, and then through the frame, up the ground wire and to the battery common.

That's about it. The final test was to power up the instruments including the rotor RPM alarm, the avionics, and the strobe lights. Then I engaged the starter. Everything continued to run flawlessly.

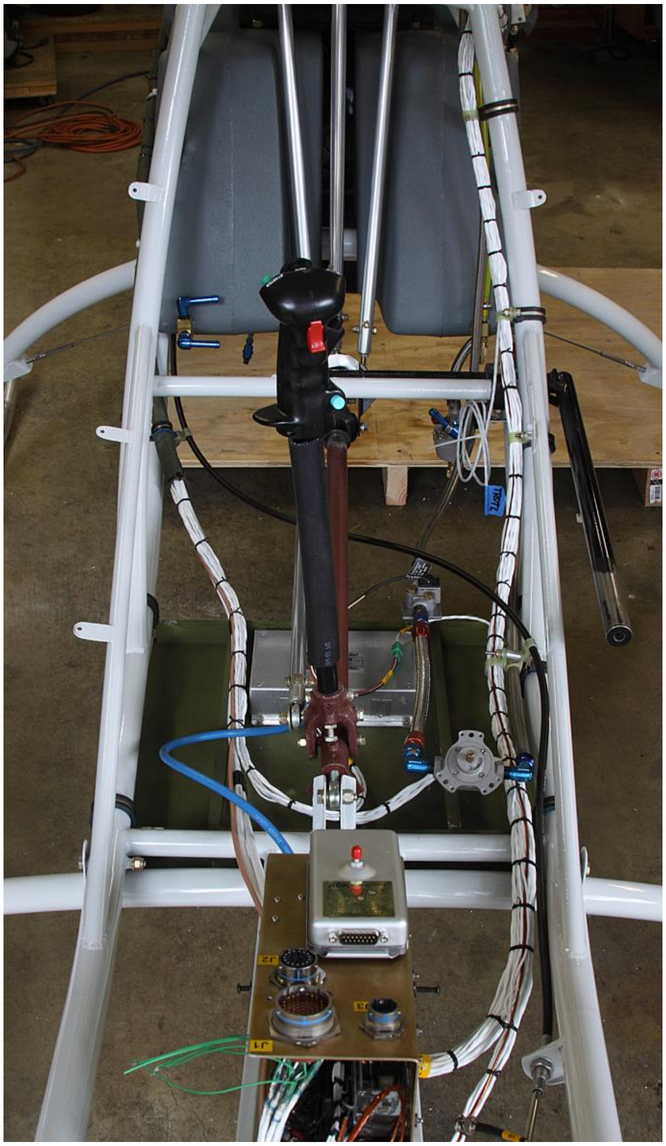
It's worth remembering that if the DC power to the engine governor goes away the engine shuts down. That could happen if any number of failures should occur in this circuit:

- F1 or F2 open
- CR1 fails open
- The ultracapacitor shorts
- The shunt fails open

That's my ten second failure mode and effects analysis (FMEA.) If all the components are in good shape none of the above are very likely to happen, but adding components to a critical circuit could degrade reliability. That's why I'm not suggesting this approach to anyone.

By the way, everyone has a current shunt in their circuit. If that path opens up then the engine will shut down. With that in mind I swapped out the standard brass nuts and lock washers on the shunt for aircraft locking nuts. I would suggest that to everyone.

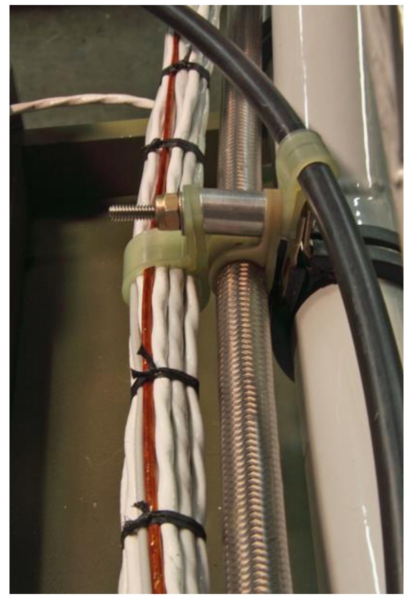
[2] The ground wire between the frame and the starter motor case also serves as a crude fuse in case the #2 AWG hot cable to the starter solenoid shorts to the frame.



Sunday 04 April, 2010 – I've completed 95% of the wiring and cabling. I ran the DC power, strobe lights, and VHF communications antenna coaxial cable down the right side and everything else down the left. This is a view looking aft from the front of the ship.

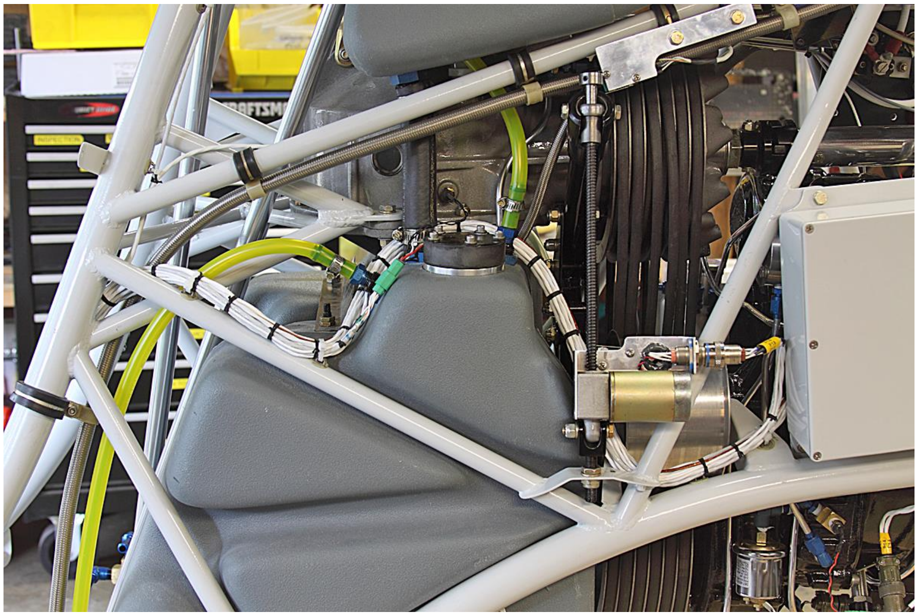
The aluminum box in the immediate foreground is the blind altimeter and the box behind the cyclic is the strobe light electronics. The transponder antenna mounts to the bottom side of the green aluminum tray that the strobe electronics is sitting on. This is all covered by the seat pan.

I've secured the cable harnesses using Adel clamps and Nylon MS25281 clamps.



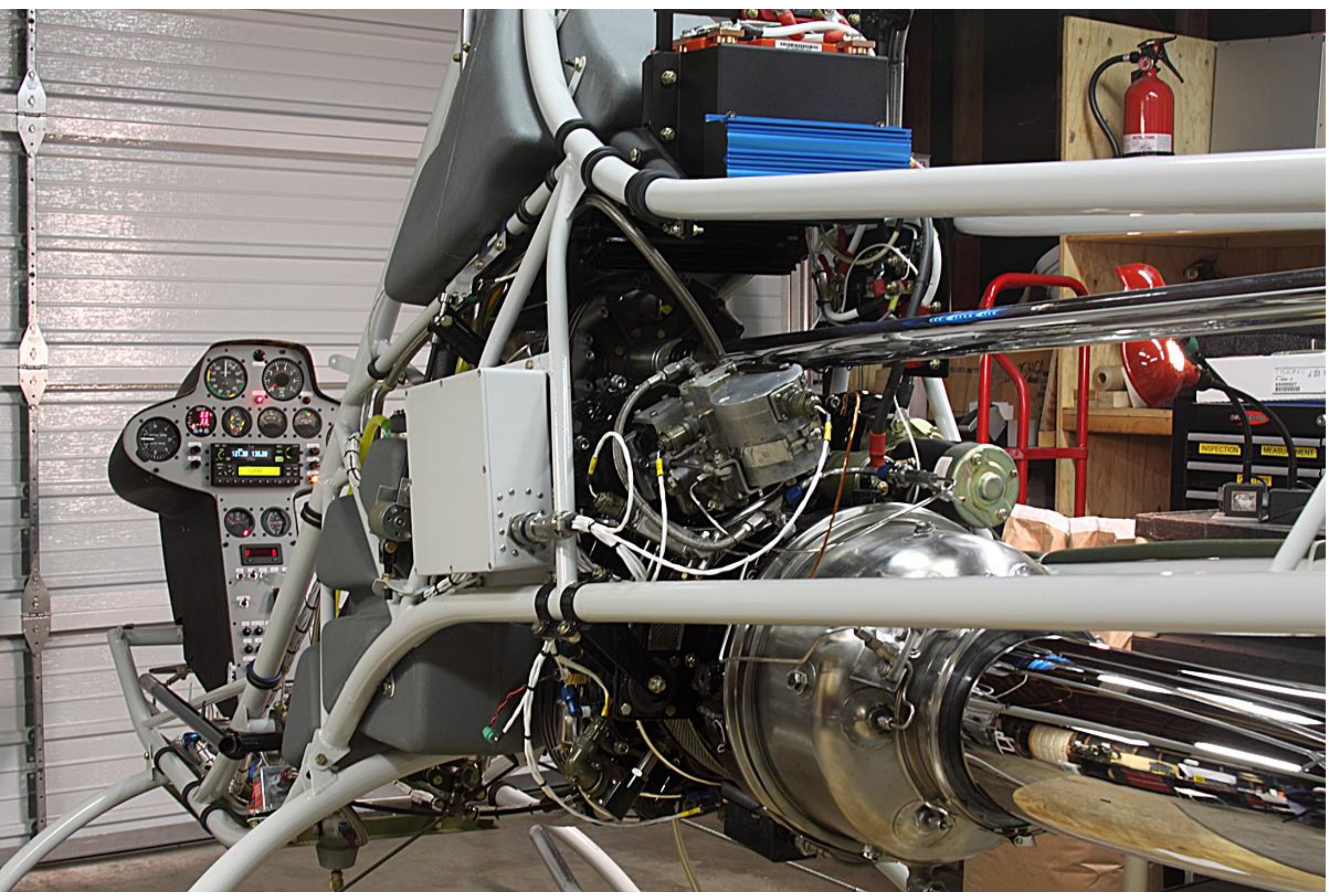
Here's another view of the front area that will be below the seat pan once it is installed.

Where I couldn't get a clamp in I've used tie-wraps.



This is the area around the lower left fuel tank. The aluminum bracket at the top of the picture mounts the upper limit switch for the clutch.

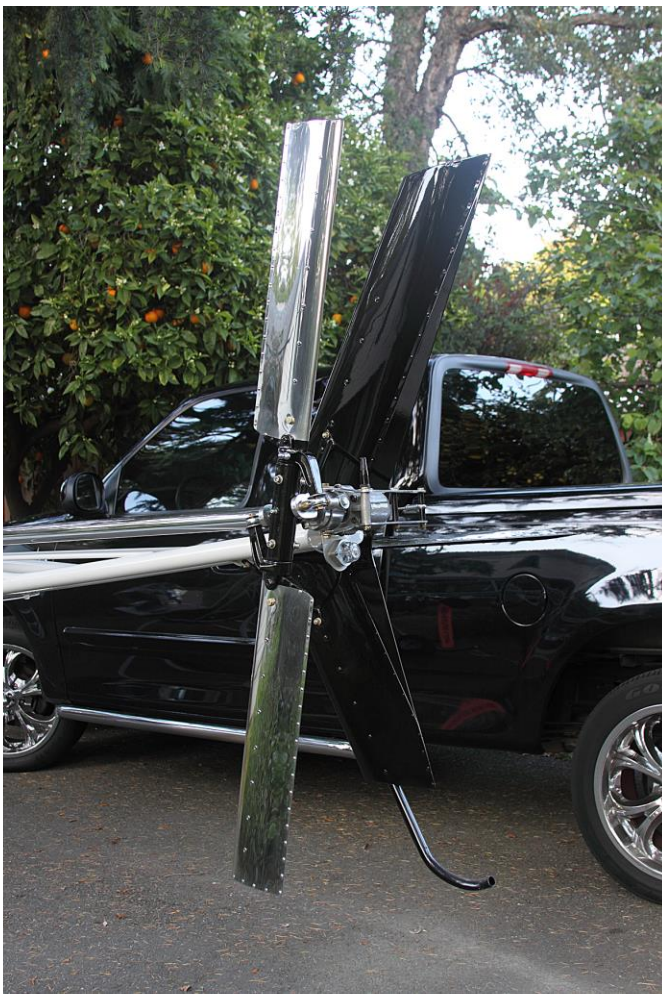
Notice how the cable harness goes around to the inside of the frame tube where the back of the seat pan will go. This will come back to bite me in about three months (see page 244)…



This is what my Helicycle looks like after almost two years of part time work. I'm getting close! I temporarily installed the instrument pod and panels to fit check the wiring and see how I'll go about installing them later when the cabin and doors are blocking access. There isn't much room in the small cabin so I'll have to be careful.

Saturday, 10 April 2010 – This is my transmission oil drain. I made it out of a scrap of 6061-T6 aluminum by running an 1/8th inch NPT tap in from both ends of the hole I drilled using a "Q" drill. This piece will mount on the plate that attaches to the bottom of the two lower tanks. The drain plug is secured with safety wire.

Here's the drain installed under the ship and between the two lower tanks facing aft.



Tuesday 13 April -- I've been trying to finish up my tail rotor for almost two years. I had it polished like a mirror and took it to a paint shop to have two black stripes painted on the tips. I wanted it to be perfect so I was willing to pay a professional to get it right. They sanded the aluminum with 80-grit sandpaper and put stripes all the way from the tip to the root. It was a total disaster. It's taken me all this time to polish out those deep scratches. It was sickening. I must have several weeks of labor invested in these two blades.

I finally know how to polish aluminum and I'm looking forward to starting on the main blades as my next big project.

So far almost everything is gloss black, gray, or polished aluminum. It's going to look nice behind my new used F-150 pickup. I still have to decide on the color of the cabin. That will be my one departure into color.

Saturday, 17 April 2010 – I'm in the very early stages of expanding my rotor RPM alarm circuit to include an expanded scale tachometer and a torque meter (see dummy instrument in upper right.)

The existing RPM alarm uses a very powerful processor and calculates the rotor RPM to a small fraction of an RPM. Right now it's loafing. Adding the expanded scale RPM indicator will be straight forward. The only complication is multiplexing all of the 50 light emitting diodes and deciding exactly how the display should look, how much averaging is required to give a nice steady display without too much lag, etc.

The torque is more complicated. Torque is a function of horsepower and RPM. The indicator will measure the twist in the main rotor shaft and derive torque from that. 100% torque will represent 90 horse power at the output shaft of the transmission – (the design limit.) Twist is measured by adding a second Hall Effect transducer and magnet at the base of the shaft just above the transmission. The time delay between pulses from the bottom and top sensors will be used to calculate the twist, then adjusting for RPM, the processor will be able to display torque. I'll grab a baseline delay measurement once the low rotor alarm turns off during start-up. That value will be stored in memory and subtracted from all further measurements. The remainder will be used to calculate twist. Obviously there is a lot more to this, but that's the general idea.

Saturday 24 April 2010 – A few weeks ago I bought a new Aluma trailer and a used F150 pickup truck. I spent the day getting ready for Hap Miller’s Central Sierra Helicopter Meet. Hap fixed me up with everything I needed. I found that I don’t have enough body weight to get the helicopter on the trailer. I loose traction going up the ramp, so I used a 12-volt winch to pull it up.

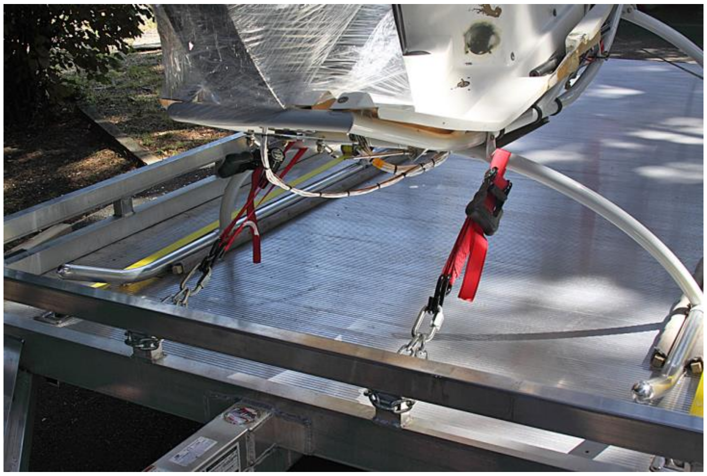
The trailer is an aluminum tandem axle car carrier with torsion bar suspension and electric brakes. In this picture the helicopter is ready to roll.

Chains run forward at each side from the rear and attach to pins that are inserted into the ground handling wheel mounting tubes. The chains are pulled tight with nylon cargo straps attached to the front of the trailer. The chains are enclosed inside of used fire hose which keep them from tearing up the trailer and making a racket.

The rear of the tail boom is supported with an aluminum frame as you see.

The front is held in place with two nylon cargo straps attached to the front bow.

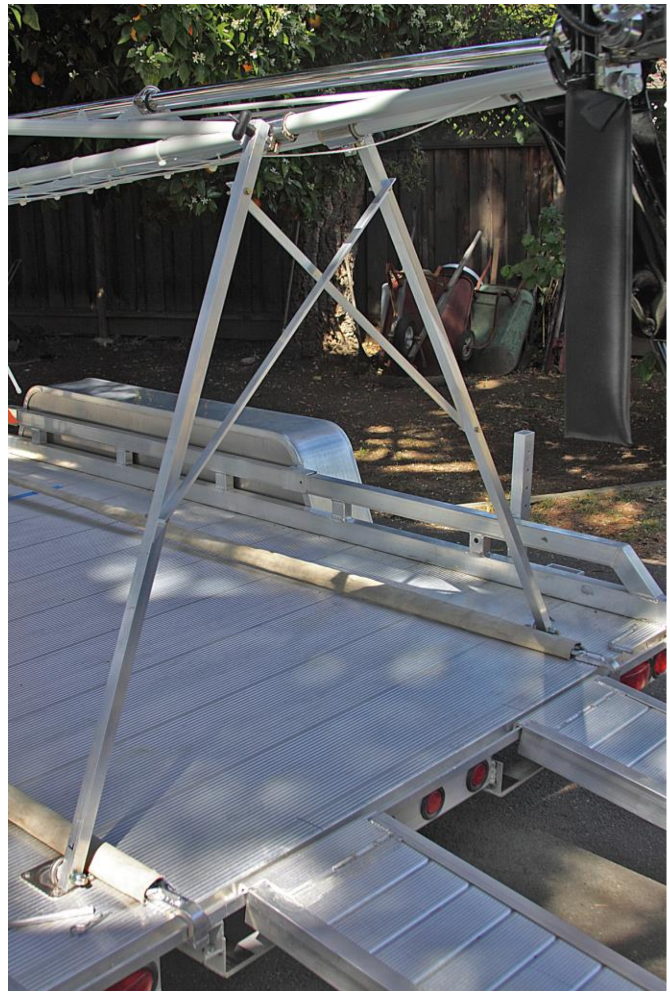
Here’s a closer view of the right hand chain showing the steel attaching bracket and eyebolt that Hap fabricated for me. It clamps around the rear of the trailer and is held in place by tension.

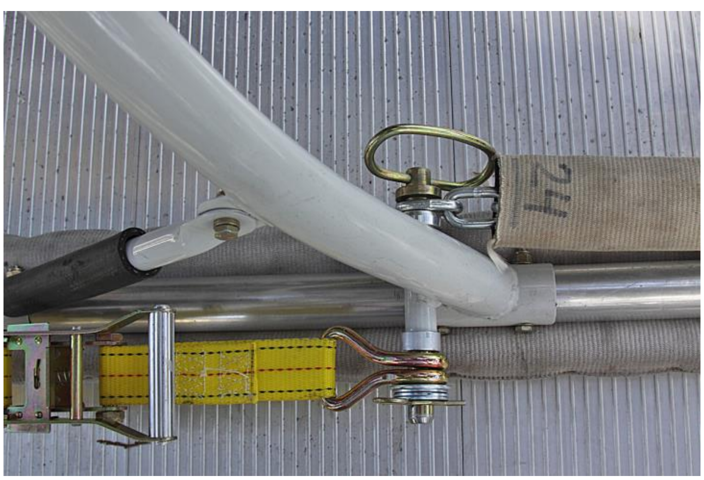


The tail boom is supported by this frame made of aluminum square and angle.

Here's a shot of the tail boom clamp assembly:

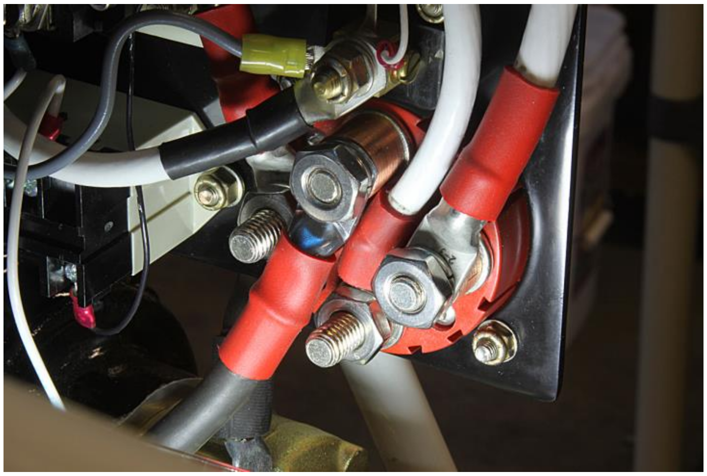
Here's the view from the front showing the two tie-downs attached to the front bow. They keep the helicopter from rocking back on its skids. Without the pilot and the cabin and doors the helicopter is tail heavy at the moment.





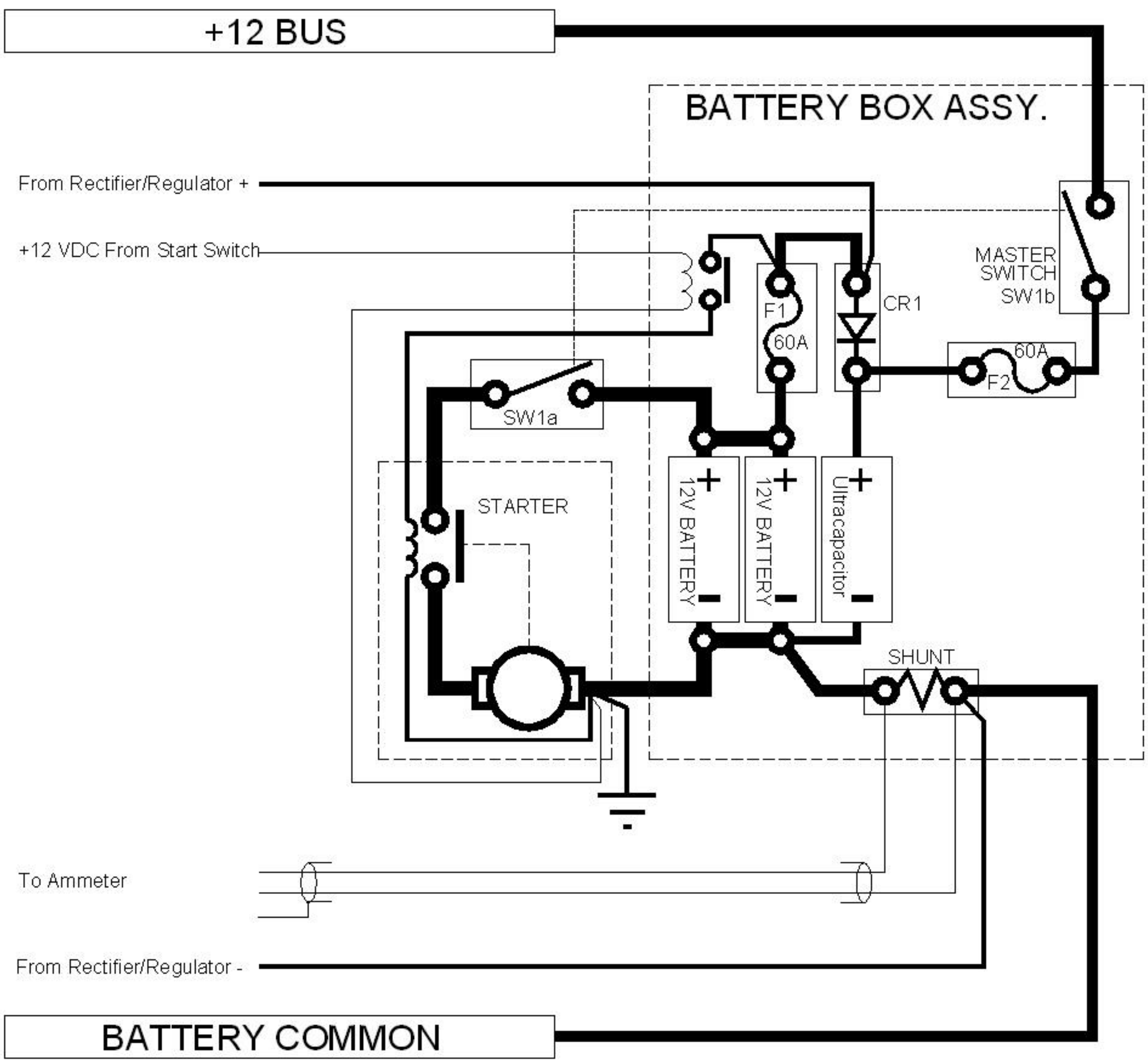
This is the chain and nylon cargo strap arrangement connected to the ground handling wheel mounting tube.

The skids also make use of used fire hose. It makes a great non-skid surface and protects the skids and the trailer from each other.



09 June 2010 – After more than a month away from my Helicycle I'm finally able to get back to it. I've replaced the original master switch with a double-pole version so I can also disconnect the starter circuit in case the starter solenoid shorts out. This recently happened to another Helicycle and it prompted me to go back and change my design. I fabricated two copper bushings so that I could stagger two of the four cables to avoid interference. I also milled out the webbing between the contact studs to allow the cables to mount as shown. The switch is a Blue Sea Systems model 6010.

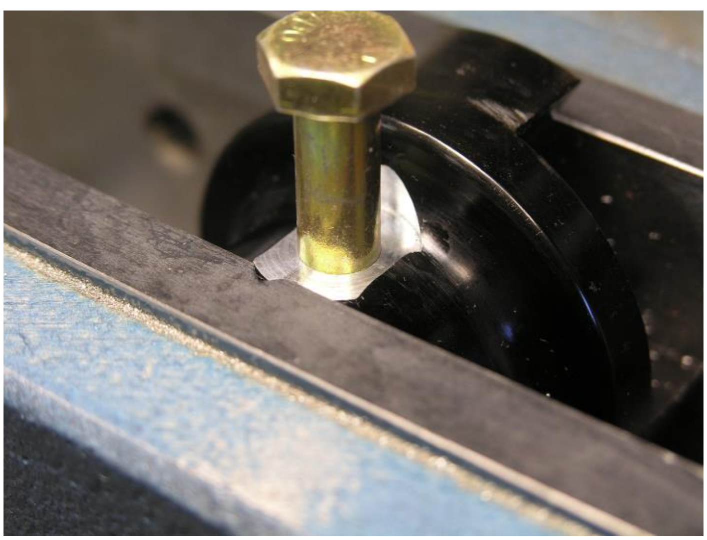
Here's the revised schematic showing the two poles of the master switch (SW1a and b.)



11 June 2010 – One of the benefits of attending a get-together like Hap Miller's Central Sierra Helicopter Meet is that you can take a good close look at other Helicycles. One of the things I noticed was that my tail rotor seemed to have excess slop compared to others. When I returned home I took the tail rotor assembly apart to find out what was causing it. I discovered that the gearbox shaft mounting holes that secure the couplings were oversized. This allowed the couplings to rotate slightly with relation to the shafts, even though the bolts were tight.

Here's an example of a hole that was so badly out of round and cockeyed that I was forced to replace the coupling. Almost all of the holes that you're required to drill or ream are critical, and almost every one on my used ship was an absolute mess. If you are thinking of purchasing a used Helicycle this is one area that you should look at very closely. I think that whoever messed up my kit must have used a hand drill. It's absolutely impossible to drill a precision hole with a hand drill. Even with a drill press it's very difficult.

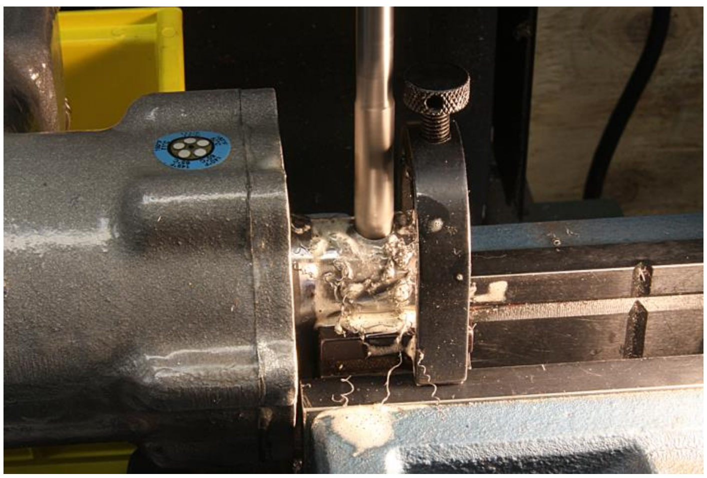
The only way to save these shafts is to bump the holes up to the next size bolt. It's either that or send the gearbox back to the factory and have both shafts replaced. Getting to this point actually took me one week. I started by ordering five AN5-16A bolts from Aircraft Spruce. I measured the diameter of each one and they ranged from 0.3100" to 0.3115". Then I ordered a 7.80mm drill and a 0.3110" straight reamer from the local tool supply.



To make the hole I lined the coupling up in the vice by tapping a 0.250" reamer all the way through both existing holes and then chucking it up in my mill. Then I carefully lined up the mill bed and vice so that the coupling was exactly in line with the reamer. Once everything was secure I removed the reamer and started enlarging both holes in the coupling; first with a 17/64", then a 9/32", and then a 19/64" drill. I finished off the top hole using the 7.80mm drill (0.3071") and the 0.3110" reamer. That resulted in a snug press fit for the bolt on the top hole, and a slightly undersized hole on the bottom. I finished off the top hole by milling a flat for the bolt head using an end mill as you see in the picture above. One down and seven to go…

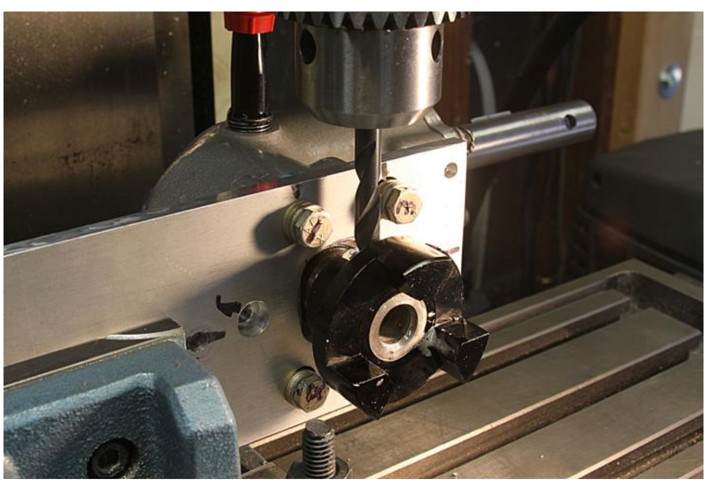
Next I clamped a v-block in my mill vice and leveled it. I put an identical v-block in the other side of the vice so the vice would grip evenly. Since the force to the jaw is applied in the middle of the jaw it would tend to grip the v-block unevenly without the second v-block to keep the jaws parallel.

The protractor says the v-block is level within 0.02 degrees but what I'm really interested in is that its exactly 90 degrees from the axis of the mill head. It appears to be very close.



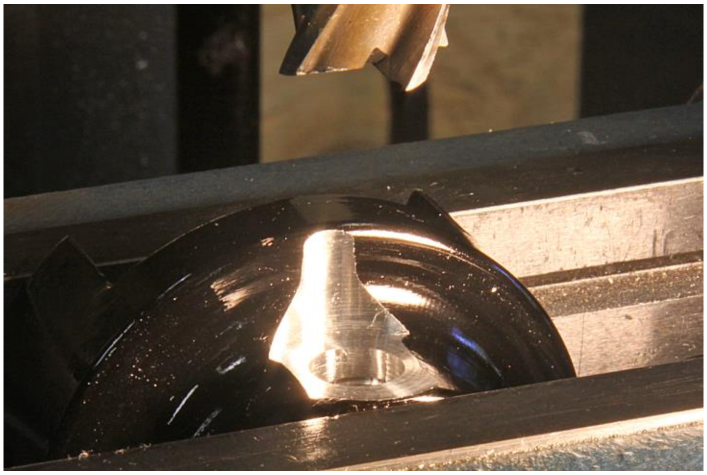
I used the same method to align the shaft in the v-block using a ¼" reamer inserted into the existing holes. Since the holes were oversized and oval I had to take my best guess. Then I used the same progression of drills and the 0.3110" reamer to enlarge the top hole. I left the bottom hole slightly undersized as I did with the coupling.

I went ahead and completed the same steps on the output shaft while I had the v-block in the vice. I want these holes to be lined up perfently so the mounting bolts will pass through the exact center of the shafts. Given the nature of the original holes I used as my reference, and my available equipment and skill level, I'm sure they're off slightly. I hope they're close enough!

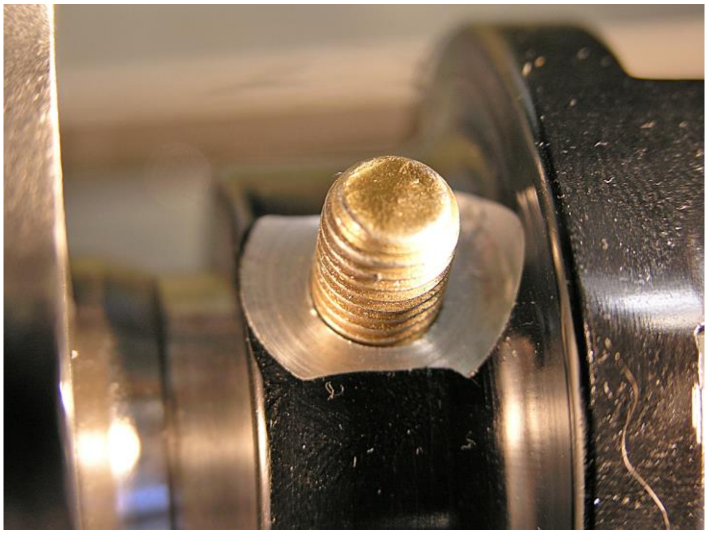


This is where it got tricky. I had no way to secure the coupling and keep the shaft and coupling holes lined up. The best I could do was to clamp the gearbox to a plate and mount the plate in the vice. That should have insured that the alignment down the long axis of the shaft was plumb. Of course I'm betting that the previous setup using the v-block and this setup were both identical. The chance of that being true is pretty low in spite of my best efforts. With this approach I let the coupling and shaft self-align as I fed the final metric drill and reamer through both sides to finish the bottom holes. There are so many things that can go wrong here that I can't count them. I will almost certainly remove some material from my perfect holes at the top while drilling through them to complete the bottom holes, but I couldn’t think of any way around it.

The last step was to enlarge the flat on the other side of the coupling so the nut will have a solid mating surface. I used the same method of sticking a reamer through both holes and using that to line up the part so the axis of the holes was perpendicular to the end mill. That should give me a flat surface at right angles to the bolt.

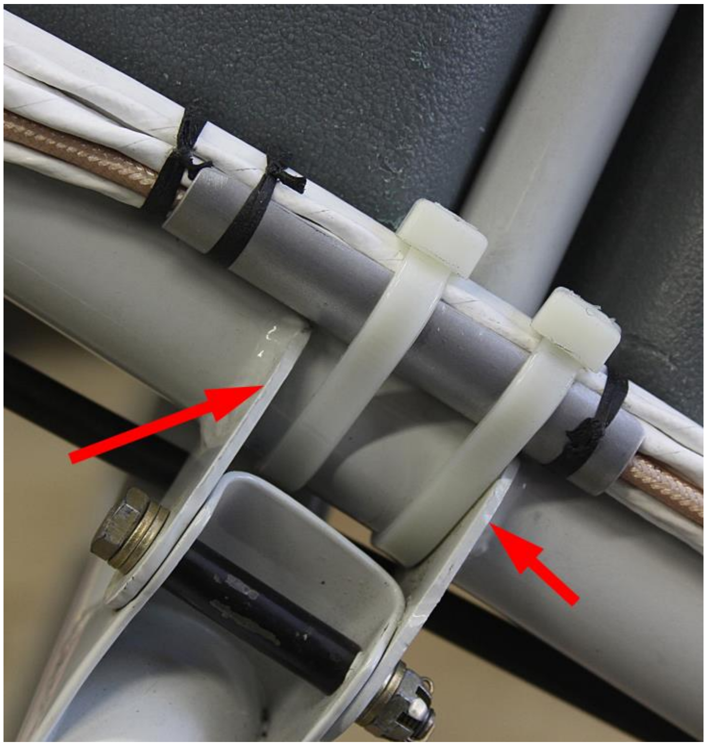


Here's the finished surface. Although I radiused the back face of the coupling so I can get a socket on to the bolt and nut there isn't quite enough room. I'll have to thin the walls of a couple ½" sockets so I can get in there to tighten that nut. I could have used a bigger end mill to remove more material but I want to keep that to a minimum.



The bolt is now pushed all the way through the coupling and the shaft. Everything lined up well. The heavier weight of the larger bolt and nut may cause a slight unbalance and some vibration. If that proves to be a problem I think the bolt could be balanced by adding washers to move the mass in line with the rotational axis of the shaft.

The last step is to repeat the process for the tail rotor coupling that mounts on the output shaft. That went without any hitches using the same steps as before. The gear box is now back on the frame and the couplings are nice and tight!



I decided to take another look at the way I'm routing my wiring down the right side of the frame. The area around the lower right fuel tank has always bothered me. I had a choice of going between the rear skid bow and the frame, or around the outside. I was concerned that the bundle might get pinched if I went with plan-A so I went around the outside. The problem with this routing is that it passes over the top of two fairly sharp brackets (red arrows.) Over time those sharp edges could abrade the insulation and cause shorts. I've decided to protect the bundle from the sharp edges by making an aluminum sleeve out of a piece of scrap 6061 tubing. I cut a slot in the top for cable access. I had intended to leave the bundle as you see it but decided to enclose it in Nomex Roundit as you see below.