Northern California Soaring Association

N41KP System Documentation

May 2019

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History

During the period of October 2018 - February 2019, Tom Anklam and I performed a major refurbishment of the electrical, oxygen, and pitot static systems of N41KP. This included the installation of a new radio, a new transponder, a new encoder, and a new electronic variometer. The new electrical and plumbing diagrams are included in this document. The instrument panels were completely disassembled, re-built, re-wired, re-plumbed, and reassembled. The following is a partial list of accomplished tasks:

- Installed new fuse block for branch circuits
- Installed new grounding block
- Modified the LiFePO3 battery, charger, and glider to use Powerpole connectors
- Removed all the old Cambridge units
- Removed old Terra radios and transponder
- Added circuit and power cord for Power Flarm
- Fabricated new wiring harnesses and installed new Becker radio and transponder
- Installed a new Becker transponder and ACK A30 encoder
- Installed new Mic and Phone jacks and wiring
- Installed a new comm radio external speaker
- Installed an external speaker for the electronic vario
- Installed a new Digital Voltmeter in panel
- Modified both panels to add Ram mounts and USB power ports
- Removed old oxygen system (had a high pressure feed to center console regulator)
- Removed old "Cessna" oxygen plugs from panels
- Installed new oxygen system with regulator/gage at cylinder
- Installed new side mounted CPC oxygen plugs
- Installed new LXNAV S8 Club electronic vario
- Repaired and fiber glassed the front and rear glare shields; installed new Camloc fasteners
- Painted and trimmed the glare shields
- Patch coated the fuselage exterior with Gelcoat to pass annual inspection.

Description of Work

The Terra radios were power hogs that kept draining the battery. Typical operation would see the radios start to fail about midday. Also, the previous owner had installed an elaborate intercom/amplifier system that no longer worked. Reliable communications were becoming a real problem. The glider had an elaborate system of Cambridge equipment which had become dated. People did not know how to use or maintain the gear.

The solution was to remove the old Terra radios and install Becker units which are more energy efficient and intended for glider battery operation. The functionality of the Cambridge units was replaced by two actions. The first was the installation of a new electronic variometer. The second was the installation of USB power ports and RAM mounts, front and rear, to allow pilots to use whatever GPS navigators they own.

The new installation has an eight (8) position fuse block of which six (6) positions are used. The remaining two (2) positions hold spare fuses. See circuit diagram.

The old and new tubing follow the standard color code system (Green=Pitot, Red=TE, Yellow=Capacity; Clear=Static).

All new wire is aircraft grade mil spec wire (Tefzel). Most joints are soldered with heat shrink tubing. Terminals are higher grade nylon (not vinyl) crimp connectors. The new speaker is an 8 Ohm encased unit purchased from Wings and Wheels and mounts nicely to the side wall of the cockpit. There was some debate about whether or not to ground the electrical system to the metal frame of the glider. Steve Radcliffe said "No" so we didn't.

The existing lithium battery is rated for 20 amps and 40 AHr and is sufficient for continued use. It is protected with a 15 amp fuse. All branch circuits are protected with 5 amp fuses. To minimize voltage drops, all wire current ratings exceed these fuse amp ratings. The battery supply wires are 14 or 16 AWG and all branch circuits are either 18 or 20 AWG.

The new wiring harness DB25 connectors were assembled using mil spec crimp pins rather than soldering.

Rear Panel

The old rear panel was modified and reused. The unused holes were plugged and soldered with a propane torch and Alumiweld. The panel was modified to add the USB power port and a Ram mount. The panel was sanded, primed and then painted using SEM products.

Front Panel

The front panel was Swiss Cheese and could not be reused. A new panel was designed in 2D CAD and was cut on a CNC Laser cutter. The old panel was one large piece of aluminum with two different bends. For simplicity, the new panel was designed with an upper and lower section and a center support

Screws

A project like this ends up being a mixture of both English and Metric fasteners. There is no getting around it, you just to have a good supply of both. Add to this the fact that instrument panel screws are traditionally black and non-ferrous (to minimize compass interference).

American aircraft instruments use # 6-32 screws, usually black oxide brass. All the English screws can be gotten from Aircraft Spruce.

The German aircraft instruments are usually Winter and they all use M4 - .7 and these can be gotten from Wings and Wheels.

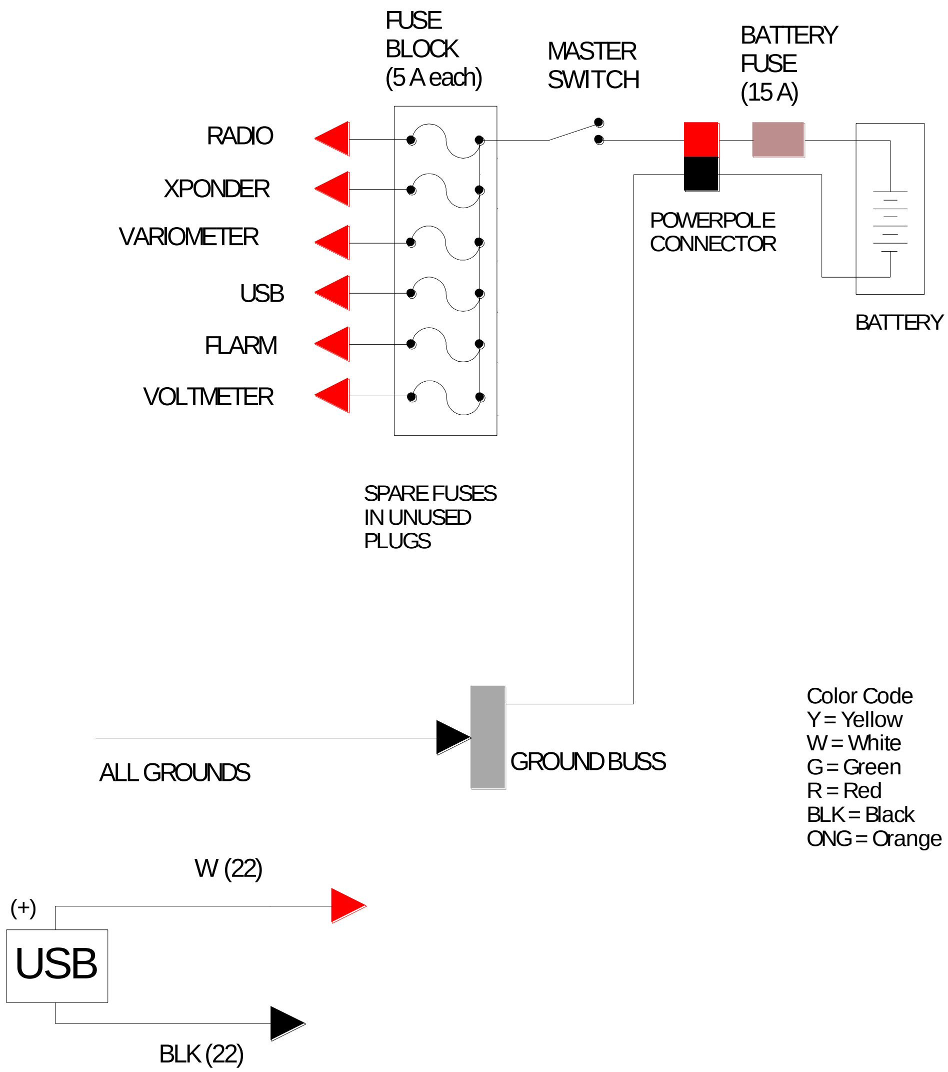
Our LXNAV S8 variometer also uses M4 - .7 screws, however, they must be custom cut to be short.

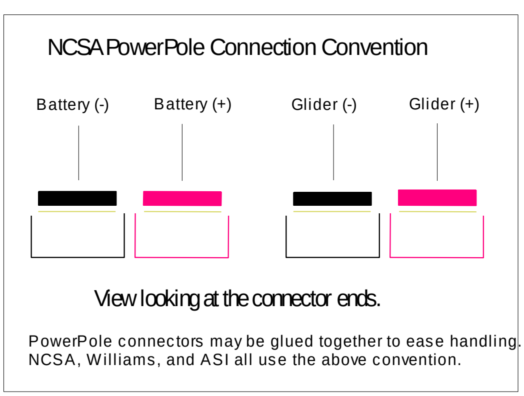
The Becker radios use a smaller M3 -.5 and these can be gotten directly from Becker USA.

Kenny Oliver
Becker Avionics
10376 USA Today Way
Miramar, FL 33025
(954)450-3137 ext:205

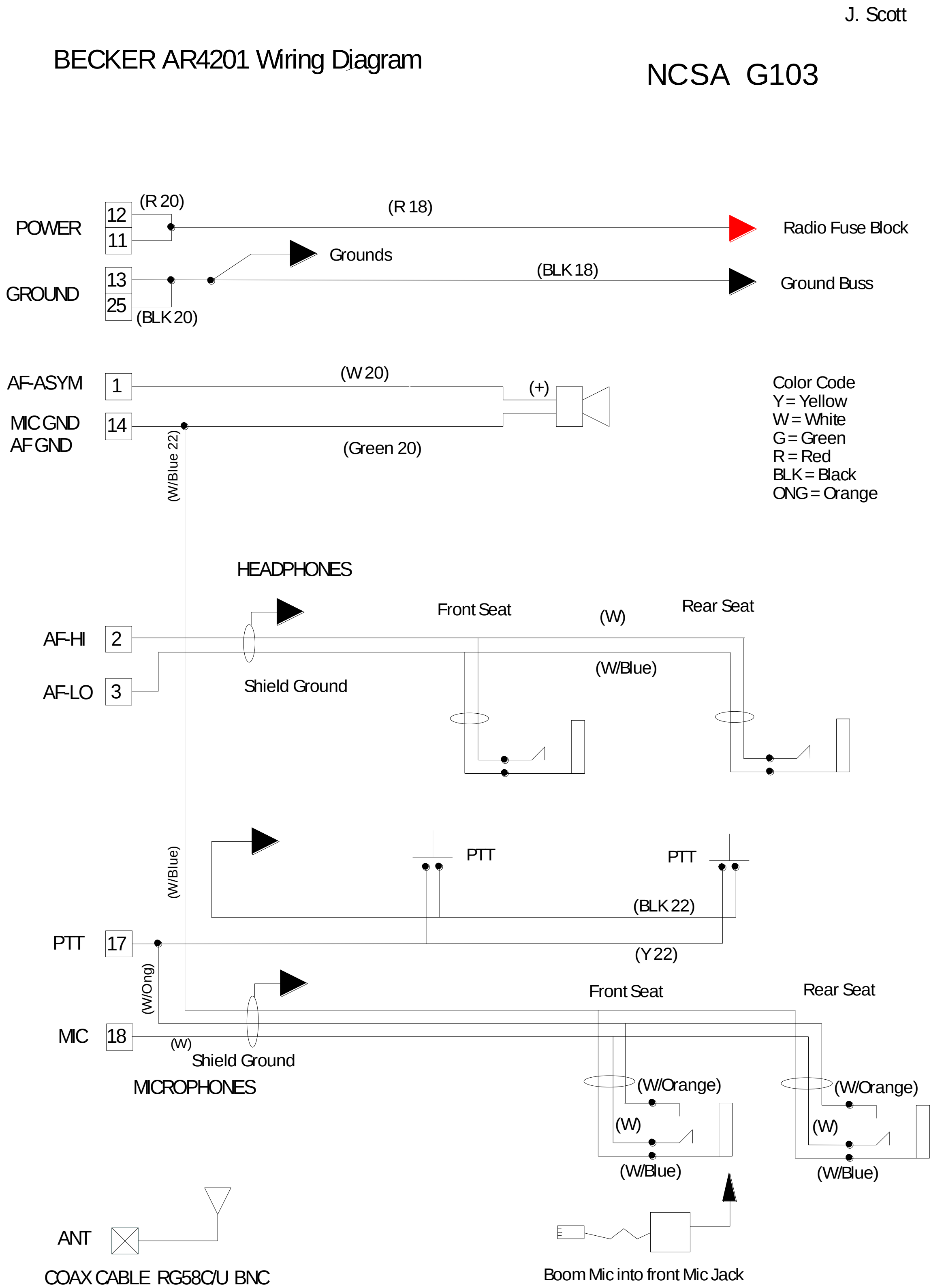
An added annoyance was that the Grob Project Manager was in love with countersunk screws. Countersunk screw heads cause fabrication and alignment issues. It also means stocking countersunk screws. It is far better to use a Pan Head Phillips screw with some mismatch tolerance on the screw/hole diameters. This conversion was done on all of KP's new work.

Electrical System Schematic

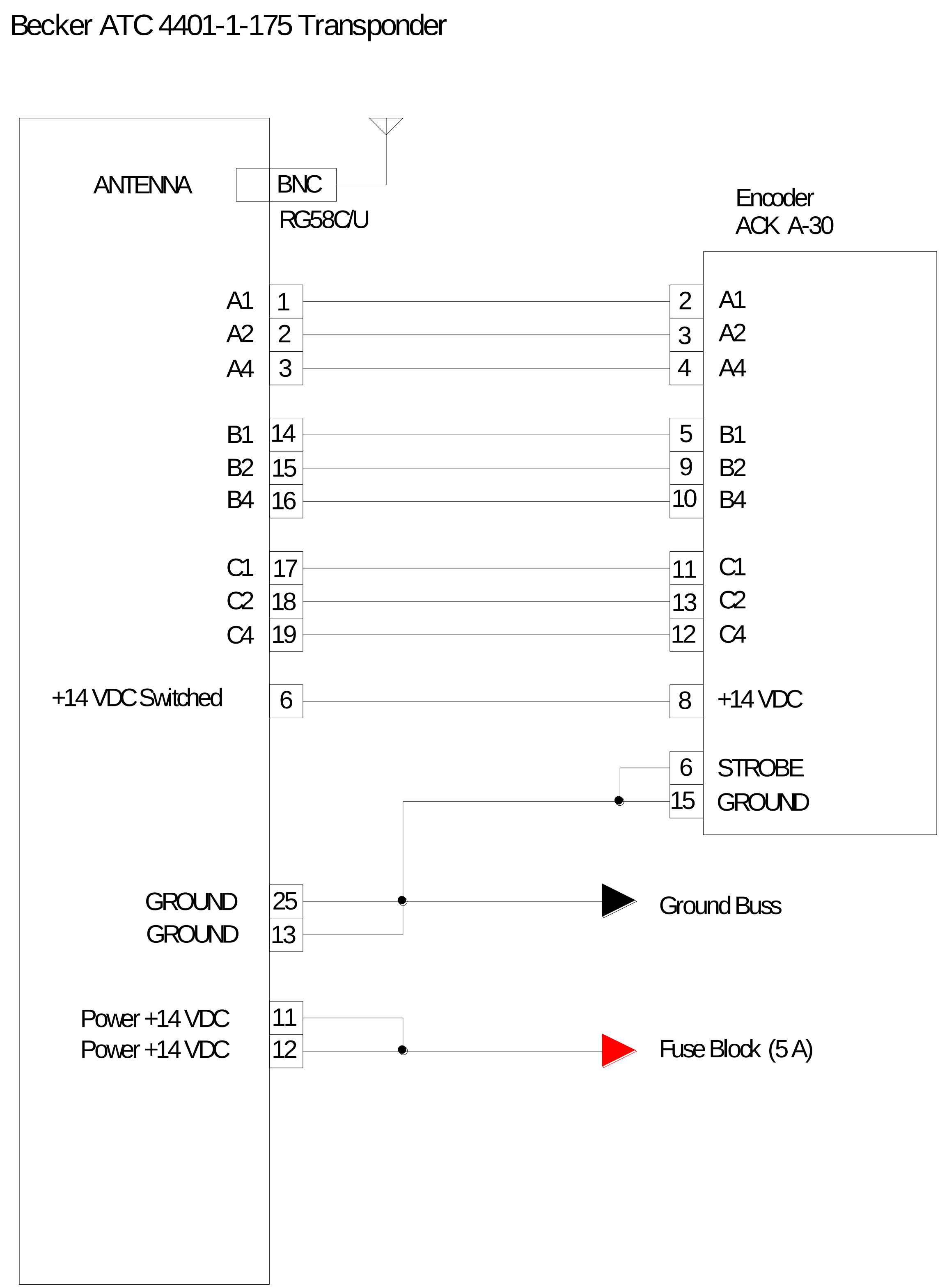




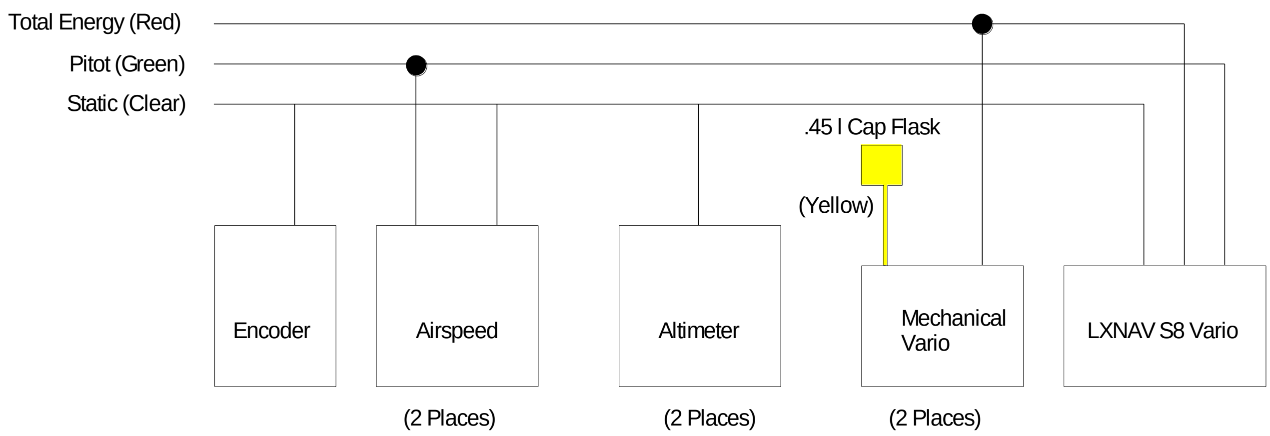
Communications Radio Schematic



Transponder / Encoder Schematic



Pitot Static Diagram



D Sub Connectors

D-Sub connectors are standard for avionics equipment. All of our current avionics use these connectors. These connectors are defined by MIL-C-24308.
Ours are Standard Density (not High Density).

Wires are attached to the connectors by the one of the two most common methods; solder pots or crimp pins. For a variety of reasons I prefer to use the MIL SPEC crimp pins. These pins require a crimping tool which NCSA owns.

The crimp connectors are also defined by a MIL Spec:

M39029/63-368   Female Pin (Socket)
M39029/64-369   Male Pin (Pin)

The avionic equipment have Male pins exiting the devices.
The cable connectors contain the Female Pins.

These Pins are rated for wire sizes 24, 22, and 20 AWG. AWG 20 gage wire is a snug fit in the connectors and is appropriate for power and ground connections only. AWG 22 is the easiest and most convenient size to use for general purpose (i.e. signals).

Wire and Fuses

Many people do not understand the purpose of fuses (or Circuit Breakers). Many people believe that fuses protect the device at the end of the wiring. They don't, the fuses protect the wiring. In the event of a short circuit, the fuse will limit the maximum current to an amount that will not damage the wiring. Once the size of a wire is known, the maximum allowable current is also known and that determines the maximum allowable fuse.

We use fuses rather than circuit breakers to minimize voltage loss and to keep the wiring simple.

The maximum allowable continuous current is determined by several factors. For our application the factors and the maximum continuous current are listed below. Note that peak currents, as needed to blow a fuse, can safely be higher than continuous currents.

Glider Application Assumptions:

Wire Length	20 feet
Voltage Drop	1 volt
Circuit Voltage	14 volts
Ambient Temperature	70 F

Wire Gage	Continuous Current (A)
14	15
16	11
18	8
20	5
22	3

Our calculated average current draw is less than 2 amps for the entire glider.

All of our branch circuits are wired with either 18 or 20 gage wire and are fused with 5 A fuses.

The battery is wired with 14 or 16 gage wire and is fused with a 15 A fuse.

All of our wiring is considerably larger than needed. We do this to minimize voltage drop.

N41KP Current Draw Calculation

The below calculation predicts that the maximum (all equipment operating) average (radio averaging assumptions) current draw is less than 2 amps.   This suggests that a fully charged battery should last all day.

Device	Standby / Operating Current Draw at 12 Volts (mA)	
Comm Radio (Becker AR4201)	278	
Transponder (Becker ATC 4401-160)	300	
Encoder (ACK A-30)	160	
Variometer (LXNAV S8 Club)	190	
USB (Powering 2 Oudies)	660	
Power Flarm	170	
	1758	
Average current draw is less than 2 amps.		
Note: The Comm radio uses differing amounts of current		
depending on what it is doing. The calculation of an "average"		
current draw requires assumptions on the duration		
of the various modes of operation.		
Assume comm radio is in standby 75%	(.75)(70 mA)=	53
Assume comm radio is receiving 20%	(.20)(500 mA)=	100
Assume comm radio is transmitting 5%	(.05)(2500 mA)=	125
		278
Assume an Oudie battery is 9600mAh at 5 volts and lasts 12 hours		
(9600mAh/12h)= 800 mA at 5 volts		
(800 mA)(5 volts)/(12 volts) ~ 330 mA at 12 volts		
N41KP is equiped with a 20 Ahr battery.		
In theory, this battery should last more than 10 hours.		

Camloc Quarter Turn Connectors

Our G103s use these connectors for the glare shields and to secure the seats. After some internet research I was able to determine that the fasteners used are the Camloc D4002 Series. The product catalog can be downloaded off the internet. Below is a brief summary.

Each Camloc connector consists of the following parts:

Grommet	D4002-O-AGV
Grommet Retainer Ring	R4G-3
Stud	D40S5-7AGV
Receptacle	D4002 Standard Type 1

The Grommet contains the Stud and the Stud screws into the Receptacle. The Grommet is retained in the attaching material by the difference in diameter between the Grommet and the Grommet Retainer Ring. This area is very small, only about 1 mm in radius. Camlocs where intended for installation in metal, not plastic. In our case they were installed into the molded ABS plastic of our glare shields. With age and abuse they simply broke thru the plastic. To fix this problem I had to fabricate metal grommet retainers and then epoxy fiberglass them to the glare shields.

<u>Grommets</u>

There are two types with the unfortunate names “Flush” and “Plus Flush”. The “Flush” grommets are truly flush and need to be counter bored into the material. Ours are the “Plus Flush” with a bulging head that only require a thru hole.

<u>Grommet Retaining Ring</u>

These snap on around the barrel of the Grommet. Use the tool T26 to install.
Once on, these are almost impossible to safely remove, and if you do succeed in prying them off, they are probably not reusable. The best way to remove them is to use a Dremel cutting disc and make a plunge cut 180 degrees from the ring ends.

<u>Stud</u>

Studs are available in a variety of lengths to match the total thickness of the combined materials. Too short and the assembly can’t be made. Too long and the assembly will be loose. Studs are installed into the grommets using the pliers tool 4P3-1.
The studs can be ordered with cross head (phillips) or blade head drives.

<u>Receptacles</u>

These are already permanently installed in the glider.

Glare Shield Fix

The Glare Shields are made of formed ABS plastic. The Camloc fasteners were installed directly into the plastic. After years of aging and abuse, they just pulled thru. The fix was to fabricate aluminum shims with the correct hole to accept the Grommet. These shims were made with “ears” and were then fiberglass bonded to the Glare Shield flanges. The flanges were then reinforced with a layer of fiberglass cloth their entire length.

Aircraft Wire

Aviation wire is often referred to by its shield material Tefzel. Tefzel is ETFE (Ethylene-tetrafluoroethylene) Fluoropolymer Resin. This insulation material is very tough, non-toxic if involved in a fire, chemically resistant, and temperature resistant. TEFZEL wire is controlled by a MIL SPEC and is quality stuff. The wire is tightly wound and does not fray apart when cut. Dimensions are tightly controlled and the wire is pre-tinned for quick and easy soldering. Tefzel wire is expensive so fabrication techniques should be designed to minimize waste. Our best vendor for wire was Wings and Wheels.

Aircraft Wire – Single Conductor

Single conductor wire is controlled by MIL-W-22759/16 and is available in all sizes and colors.

M22759/16-XX-Y
M22759/32-XX-Y

The specs /16 and /32 are functionally equivalent for our purposes. The difference is a slight difference in the Tefzel insulation.
The above product information is embossed on the outside of the insulation which makes it very convenient to determine what you are holding.

XX is AWG wire size
Y is a color code

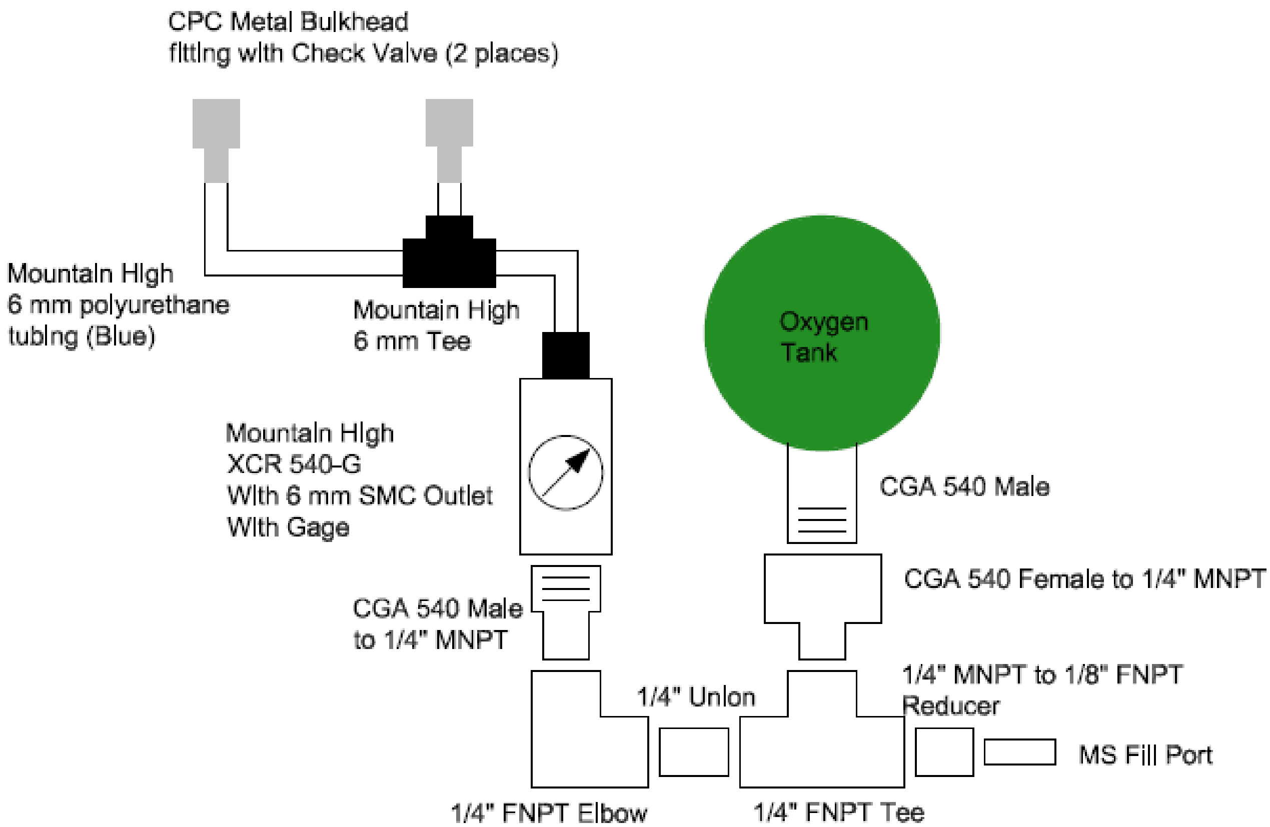
Aircraft Wire – Multi Conductor

Multi-Conductor wire is controlled by MIL-W-27500. We buy the shielded stuff and use it for headphones and microphones. We only use AWG 22 gage to be most compatible with D-Sub connectors.

M27500 – 22YY3XX
22 is the AWG wire size
3 is the number of conductors

The above product information is contained on a white strip of paper located inside the shielding.

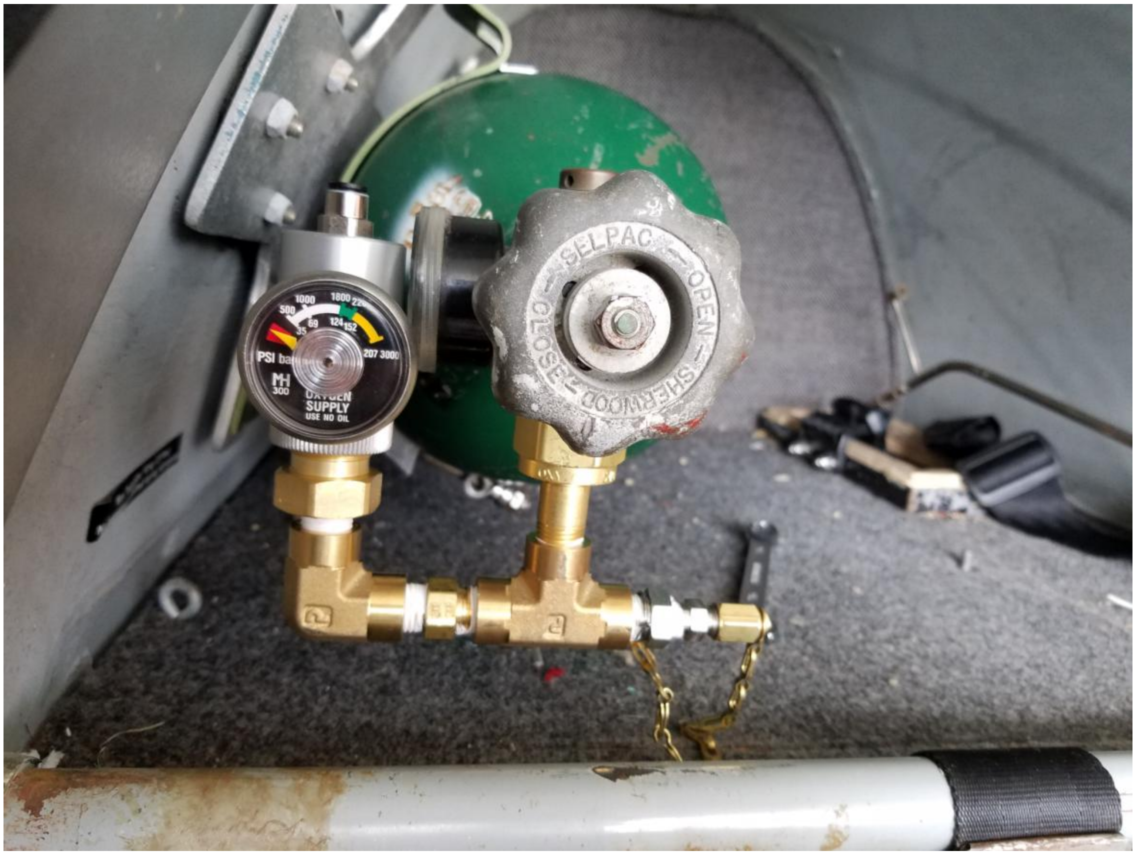
Oxygen System



The folks at Mountain High make some hardware that is well suited to our needs. Their regulators are low pressure and high flow rate which is what we need for our aviation use. Their XCR series regulators supply plenty of air to support two pilots with one 6 mm supply line. Mountain High sells special purpose polyurethane tubing in two common sizes, Red (4 mm OD) and Blue (6mm OD). Their fittings seal on the outside diameter of the tube which leaves the entire inside diameter open for minimal flow resistance (as opposed to hose barbs). When ordering the regulator you must specify that you want the 6 mm outlet rather than the 4 mm outlet which is standard for a single pilot.

The various metal fittings (upstream of the regulator) must be the higher quality, higher pressure rated units. Insure that all components are rated for 3,000 PSI service. These components can be ordered from Mountain High, or a welding supply house, or a hydraulics supply house. DO NOT BUY THIS STUFF FROM HOME DEPOT. Their products are not rated for 3,000 PSI service.

The MS fill port is a somewhat hard to find item. It is documented by a mil spec; MS22066 (3/8 – 24). It is sometimes referred to as a “Schrader Valve” because it has a center check valve that looks like a Schrader valve. Our’s came from Mountain High.


SELPAC
OPEN
CLOSE
SHERWOOD
SUPPLY
USE NO OIL

CPC Connectors

It was desired that we pick a type of oxygen connector that could become standard for our fleet. After some research we decided on CPC connectors (Colder Products Company). These are commonly found in gliders, are readily available, and are cost effective. The parts can be purchased in either plastic or metal. We got ours from Mountain High.

For convenience, we choose to mount ours in the lower right side of the seat. As a precaution, we fabricated dust caps to prevent debris from getting into the unprotected bulkhead connectors.

Zip Tie Mounts

Zip Ties are extremely useful for draping wires and tubing. Unfortunately, the adhesive mounts for the Zip Ties usually don't survive the years of heat and environmental insult. Half of the mounts in KP had popped off. In researching a better product I found a system that is popular with the marine industry. The pads come without any adhesive and you mix the adhesive separately when ready. You "butter" on a generous amount on the foot of the mount and then stick it onto a properly prepared surface. The adhesive is a two part acrylic system that is designed to stick to many different materials but is especially well suited to fiberglass (think boats; they are more boats than there are gliders). This adhesive system is sufficiently viscous that you can stick these to a vertical surface and they will stay put while curing. The adhesive comes in a dispenser with a very well designed "reusable" cap that actually works.

See the above oxygen pictures for an example installation.

Panel Fabrication

The panels are best machined by generating a CAD design and saving the file as a .DXF file and giving that file to a machine shop with a CNC laser or water jet cutter. The most difficult part of generating the file is capturing the freeform shape of the panel exterior. To do this I laid the removed panel on my kitchen table and used tape to construct an X, Y coordinate system on the front face. I made Y (vertical axis) the independent variable with divisions every 0.25 inch. At each Y division I then measured the total width and divided by 2 to get X. These points were used in the CAD program to create a point-to-point polygon shape. Although not a true and smooth curve, it is good enough. If you look closely at KP's front panel you can see the scallop of the line segments. The panel is symmetric so once the half shape is entered in the CAD program a mirror image flip completes the panel. All CAD programs have a feature that allows you to join polygons into a continuous element. You need to do this to avoid problems with the CNC cutter coming back with an error message about "unconnected line segments". Do this to make the panel outline a continuous arc.

All standard aviation instruments are of two round sizes; 80 mm (3.125 inch) and 57 mm (2.250 inch). Note that these are nominal numbers since the English and metric conversions are not exact. These numbers refer to the minimum diameter of the hole in the panel. The instruments are supposed to be slightly smaller to fit. Remember that a layer of paint will subtract from the opening. English instruments usually use #6-32 (.134") attachment screws while the German instruments use M4s (.151"). For the large instruments, recommended practice is to cut a hole of 3.170 inches and screw holes of 0.170" for #6-32 or 0.177" for M4.

Once the panel freeform is modeled it becomes very easy and very helpful to experiment with different instrument configurations to see what fits and how they look. Remember to model the dimensions of the instruments behind the panel since this is where the interferences will occur. Since instruments faces are round and the corners are square, interferences at the corners are not usually the problem. Usually it is the edge-to-edge clearances that are issues. Usually a separation of 0.200 inches (not very much) is sufficient, but check to make sure.

Be sure to test fit all of the instruments and all of their attachment screws prior to painting.

The KP panel was spray-can painted using the following SEM products:

Primer:	Self Etching – Gray #39683
Color:	Presidio (Gray) #15163
Clear Coat:	Low Luster – Clear #13023

Powder coating would be preferable, but would take more money and more time. Consider powder coating for next time.

Boom Mic

As an experiment, we installed a Boom Mic (Gooseneck) in the front seat cockpit. It is hoped that students and pilots will find this easier to use than a hand mic. Installation of a Boom Mic posed several installation options which are discussed below.

Such mics come in two (2) types; aviation and dynamic. The AR4201 radio can accept either type but the signals go on different pins. We chose the higher output aviation type because we finally decided on the option [3] configuration.

[1] Direct Connect
Wire the boom mic directly to the radio. Do not have headphone and mic jacks. This option was rejected because we wanted to have the headphone and mic jacks for those who wish to use headsets. We also wanted to maintain the hand mic option in case the boom mic ever failed.

[2] Wire Boom Mic in Parallel with Mic Jack
It was assumed that we would need a switch to disable the boom mic when people used a headset (to avoid an echo). Our concern was that someone would turn the boom mic off and the next person would wonder why the radio did not work.

[3] Plug the Boom Mic into the Mic Jack
We went with this option. It is the best implementation of the KISS principle. The boom mic can be unplugged to use a headset. If left unplugged, the problem should be immediately obvious. If the boom mic ever needs to be replaced, this would be the easiest configuration to switch.

Lessons Learned

The MIC and PHONE jacks in KP were modular units which allowed close spacing. We are using open frame Switchcraft plugs which are bulkier. Next time leave more space between the plugs.

Fabricating the front panel in two pieces with a center bracket was not such a good idea. It worked, but fabricating the center bracket and then match drilling it to the support walls was more trouble than it was worth. Next time, fabricate it as one piece as was original.

I was a little disappointed with the tube connection on the ACK A30 transponder. Next time consider spending a few extra dollars and getting a Trans Con unit with a threaded (1/8 NPT) connection port.

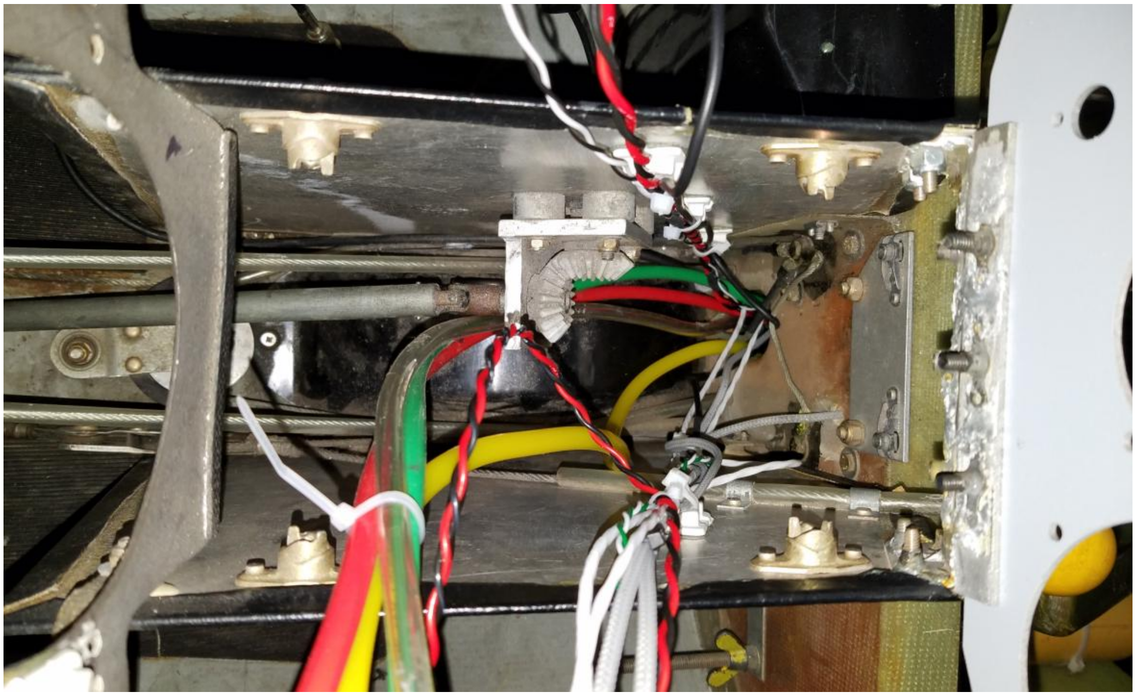
Now that we have the CAMLOC tools, we should replace all the flat head CAMLOCs with cross heads (phillips head). This makes it much easier to hold the screwdriver in place while pushing and making the quarter turn.

Removing the oxygen bottle is not as hard as it looks. Next time just pull it and get it hydro tested if needed. Remove and plug unwanted (unused) gages or install a different valve. The selected Mountain High regulator already has a gage installed which simplifies the manifold plumbing.

Remember to test fit all the instruments prior to painting.

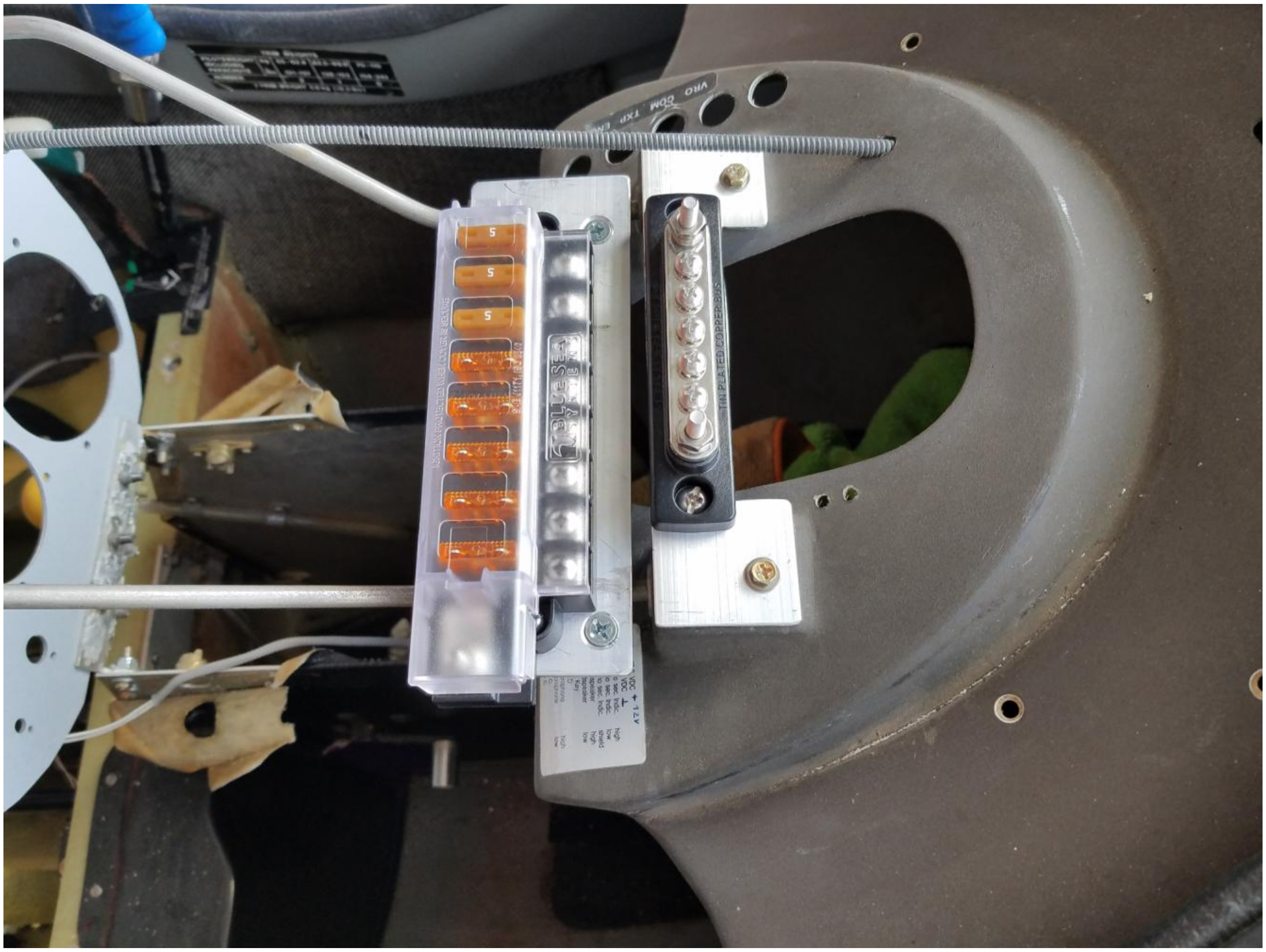
Photos

Everything starts with disassembly.



When laying out the instruments in the CAD drawing, remember to check to see if obstructions lay behind. The 90 degree gear mechanism that adjusts the pedals turned out to be an interference with the transponder. Some of the bracket had to be trimmed away.

The “A” Team.



The Ground Buss was mounted to an aluminum plate which was then mounted to the fiberglass frame of the glider. I liked to use hex head machine screws and a nut driver; it makes handling easier. There is a nylon lock nut underneath.

The Power Buss was mounted to an aluminum plate that then mounted to the support rods of the instrument panel. A pattern of four (4) Adel cable clamps attach the plate to the two rods. Some thought and layout must be given to insure that the Buss screws and the Adel screws all fit without interference and are all accessible.

New Rear Panel

New Front Panel

END