Collar Construction

General Soldering Instructions

1. Set the temperature of the soldering iron between 700 to 750 degrees F. You may need to experiment and adjust your iron temperature to better suit your particular iron, tip, and solder. We have used fine-pointed tip with 0.56 mm diameter, 60% tin/40% lead, 5-core solder will good success at this temperature.

2. Prior to soldering, prepare the tip of your soldering iron. Cold shock the pre-heated tip on a damp sponge and wipe the tip clean. Finally, tin the tip with solder. Repeat this process when the tip becomes fouled with flux resin, carbon, and other debris.

3. When soldering, particularly on small and/or heat-sensitive parts, do not apply heat too long in one area of the part. Many electronic parts are heat sensitive and can be ruined by holding the iron in one place to long. Allow heat to dissipate by soldering a contact at one end or side of the part then move to a contact on the opposite end or side of the part to continue soldering. Where all the contacts are close together on one end or side of the part, you may need to pause for a few moments in between soldering each contact to allow heat to dissipate.

4. Placing a small part in its proper place on the PCB and keeping it there during the soldering process can often be maddening. Low-tack tape or small, padded alligator clips can be helpful. Another useful approach is to load the iron tip with a slight excess of solder, then hold the part in place using tweezers or a dissecting needle held in your off hand, tack one contact of the part with the loaded tip, check the part for proper alignment and reheat and adjust, if necessary. Then, solder two different contacts (preferably on the opposite sides/ends of the part) in place with ample solder. Now you are free to properly solder the tacked contact and all other contacts on the part.

5. After soldering has been completed on a part, double-check all the contacts (with a magnifying glass, if necessary) to make certain that there are no solder joints bridging across contacts. If a bridging joint is found, you may be able to remove the bridge by stroking the iron tip between the affected contacts. If there is a slight excess of solder in the joint, this solder may be displaced by pushing it along one contact with the iron tip. If there is just too much solder in the joint, use a soldering wick (copper braid) to remove wick-up/remove some or all the solder.

6. When finished soldering, clean and tin the iron tip to prevent corrosion and then turn off the iron.

Assembling the Collar Electronics

Sequence of Components in the Assembly

1. 1 Printed Circuit Board (PCB), custom
2. 1 GPS receiver, TIM-LF, u-blox, surface-mount
3. 2 capacitors, 10 uF, surface-mount
4. 1 resistor, 10 ohm, surface-mount
5. 1 regulator, 3.3 V output, Linear Technology, surface-mount
6. 1 coin-cell battery holder, 2032-size, surface-mount
7. 1 GPS antenna jack, 5-contact, through-hole mount
8. 1 GPS configuration header, 6-pin, through-hole mount, **optional**
9. 1 main power cable with 2 male contacts and housing
10. 1 radio power cable with 2 female contacts and housing
11. 1 stereo jack, 3-contact, surface-mount
12. 1 reset button, 4-contact, surface-mount
13. 2 transistors, N-FET, surface-mount
14. 1 single-board computer, CF2, Persistor Instruments, through-hole mount
15. 1 spread spectrum radio transceiver, AC4490, Aerocomm, through-hole mount

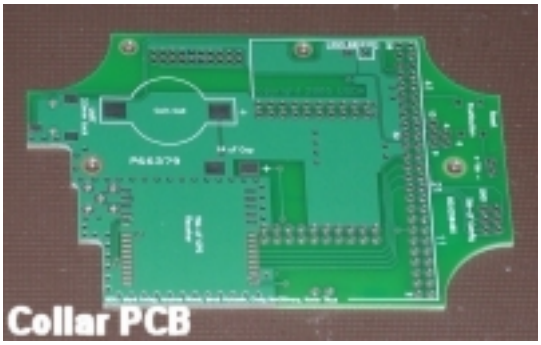
The Bill of Materials for the collar is available at:
http://clark.nwrc.ars.usda.gov/collars/Collar_BOM.htm

Assembly Instructions

Printed Circuit Board (PCB)

1. Wondering where to get the collar PCB? The Gerber files and an example order specification/quote used in ordered the PCBs are available on the Purchase Materials page (http://clark.nwrc.ars.usda.gov/collars/purchasing.php).

2. Use the white silk-screen legend on the PCB to identify where each electronic component should be mounted.



3. Many parts have polarity, so take note of polarity notations on the part and PCB.

GPS Receiver

1. Apply liquid flux (rosin-based) to all 30 of the solder pads designated, on the PCB, for the GPS.

2. Place the GPS on the PCB so that all 30 contacts of the GPS line up with the solder pads on the PCB. The GPS can only go on one way.

3. Clip the GPS in place with a small, padded alligator clip (you can use non-conductive tape as padding). Alternatively, if you are steady, you can hold the GPS in place with a finger of your off hand.

4. Apply liquid flux (rosin-based) to the contacts and solder pads.

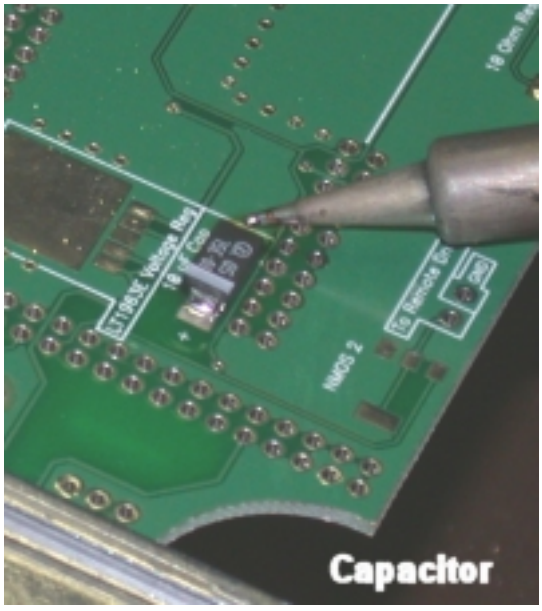
5. Load your iron tip with a slight excess of molten solder (solder will droop slightly from the underside of the tip.

6. Tack a contact on one corner of the GPS to the solder pad on the PCB. This is done by first contacting and heating the pad (and thus indirectly heating the contact) with the iron tip, then using the iron tip to wipe solder up onto the GPS contact. Double-check GPS for proper alignment relative to the remaining pads on the PCB. Repeat this tacking procedure on a contact in the opposite corner of the GPS.

7. Load your iron tip and begin soldering on the more distantly-spaced contacts of the GPS. Alternate where you are soldering, by shifting from one side of the GPS to the other, to avoid overheating the part.

8. You can smooth and equalize the amount of solder in each of these solder joints by cleaning the iron tip and then slowly dragging the unloaded tip horizontally across one from joint to joint. Repeat on the opposite side.

9. Load your iron tip and solder the more closely-spaced contacts of the GPS by simply dragging the iron tip horizontally from contact to contact making sure that the iron tip is applying heat to both the contacts and pads simultaneously. Repeat this operation, only use an unloaded iron tip, to smooth and evenly distribute the solder along all the joints.



10. Use a magnifying glass or loupe to inspect all your solder joints on the GPS. Make certain there is no solder bridging between contacts.

Capacitors (10 uF) -- Total of 2

1. Apply liquid flux to the 2 pads designated, on the PCB, for one of the two capacitors (10 uF).

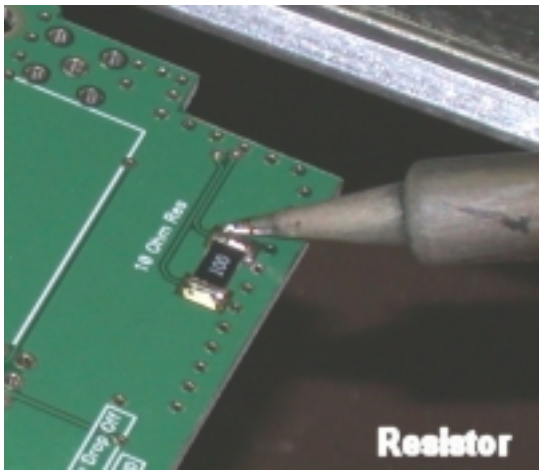
2. Place the capacitor on the PCB so that the marked end (white stripe) of the capacitor is positioned over the pad marked "+" in white silk screen.

3. Hold the capacitor in place with tweezers. Check that the capacitor is centered between the 2 pads. Use a loaded iron tip to tack one end (contact) of the capacitor to a pad. Check for alignment and adjust if necessary by nudging the part or re-heating and re-positioning the part.

4. Solder the opposite end of the capacitor, applying most of the heat to the pad and using a length of solder (held in the off-hand) to supply ample solder to the joint. Repeat on the tack joint of the opposite end. Repeat the entire process for the remaining capacitor located on the opposite side of the board.

Resistor (10 ohm)

1. Apply liquid flux to the 2 pads designated, on the PCB, for the resistor.



2. Place the resistor on the PCB, centered over the 2 pads, and hold in place with tweezers. There is no polarity in this part so, you do not have to be concerned with "which end goes where?". Tack one end (contact) of the resistor in place using a loaded iron tip. Check for proper positioning and adjust, if necessary.

3. Solder the opposite end of the resistor, applying most of the heat to the pad and using a length of solder (held in the off-hand) to supply ample solder to the joint. Repeat on the tack joint of the opposite end. This is a small part so, be careful not to allow the iron tip to linger on the part.

Regulator

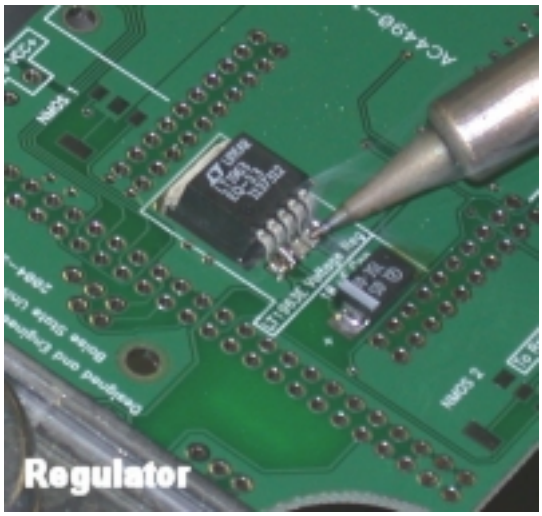
1. Apply liquid flux to the 5 small pads and 1 large pad designated, on the PCB, for the resistor.

2. Place the resistor on the PCB, aligned over all the pads, and hold in place with tweezers or a finger tip of the off-hand. The large pad is a bit small for the part, so slightly slide the part towards the 5 smaller pads until the edge of the large pad can be

seen above the top edge of the heat-sink portion of the part. Be certain you can still see some of each of the 5 pads extending beyond the 5 regulator contacts.

3. Using a loaded iron tip tack one of the 5 contacts to its pad. Check for proper alignment and adjust, if necessary. This part is difficult to de-solder so, make certain you have it position where you want it before proceeding.

4. Solder each of the remaining contacts on the regulator, applying equal heat to both the pad and contact, and using a length of solder (held in the off-hand) to supply ample solder to the joint. Be careful not to apply too much solder as the 5 contacts on this part are prone to forming bridged solder joints.



5. Drag a clean, unload iron across the 5 solder joints to smooth and evenly distribute the solder.

6. Inspect the joints with a magnifying glass and repair any bridging joints.

7. Using a loaded iron tip, apply heat to an upper corner of the heat-sink portion of the part and to the pad. Slow drag the iron tip back and forth across the whole upper edge of the part, thus heating the entire heat sink, until you see the solder from your iron begin to wick under and along the heat sink. Using a length of solder (held in the off-hand), form a solder joint completely across the upper edge of the heat sink portion of the part. This last solder joint allows heat transfer from the regulator to a larger heat sink (i.e., the copper layers of PCB itself).

<u>Coin-Cell Holder</u>

1. Apply liquid flux to the 2 pads designated, on the PCB, for the coin-cell holder.

2. Place the holder on the PCB, aligned over the pads, and hold in place with tweezers or fingers of the off-hand. This part has polarity, so be certain that the contact marked with "+" is aligned over the pad marked with "+". When in proper position, the opening of the holder (i.e., where the coin cell is slide into place) should face towards the edge of the board rather than towards the interior.

3. Using a clean iron tip, apply heat to one of the contacts until solder becomes molten and wicks under and around the contact when touched to the heated contact. This may take a while because the contacts on this part are large thus forming substantial heat sinks. This part is not particularly heat sensitive but the plastic portions with melt if you hold the iron against them.

4. Check for proper alignment and correct, if necessary. Repeat for the remaining contact.

GPS Antenna Jack

1. Apply liquid flux to the 5 plated holes designated, on the PCB, for the GPS antenna.

2. With the top-side of the PCB facing up (Note: the coin-cell holder is on the top-side of the PCB), insert the 5 contacts of the antenna jack into the plated holes. When in proper position, the jack should point away from the coin-cell holder and towards the edge of the PCB.

3. While holding the jack in place, invert the PCB (i.e., bottom-side up) and place the PCB, with jack still inserted, on a heat-safe surface (Note: jack will get quite hot during soldering). Use shims to position the height of the PCB above the surface so that the contacts of the jack protrude slightly and evenly above the bottom-side of the PCB.

4. Using a loaded iron tip, tack the center contact of the jack to its plated hole by applying heat equally to both until the solder wicks into the hole.

5. Check that all the contacts are protruding an equal amount above the bottom-side of the PCB. Invert the PCB and confirm that the jack is mounted plumb in both directions. Adjust, if necessary, by nudging the part.

6. Invert and re-position the PCB with the bottom-side up. Apply heat to one of the remaining contacts and holes (i.e., do not disturb the center contact for now) until solder from a length held in the off-hand begins to wick into the hole. Continue applying heat and solder until solder begins to appear on the top-side to the PCB (i.e., the solder has wicked completely through the hole. Repeat for the remaining unsoldered holes and then apply to the tacked center hole.

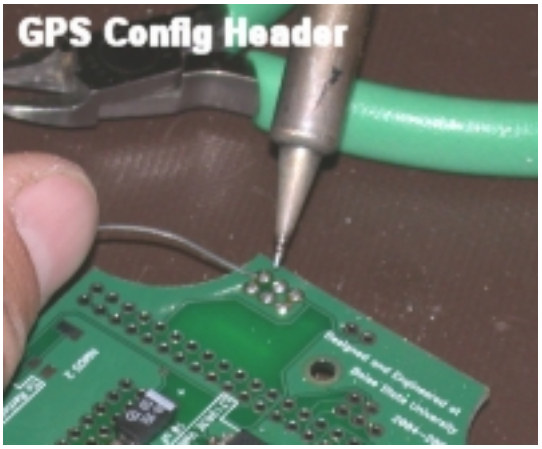
GPS Configuration Header (Optional)

1. Apply liquid flux to the 6 plated holes designated, on the PCB, for the GPS configuration header.

2. Using a small pair of side cutters, cut off a 6-pin section from the break-away header part.

3. With the top-side of the PCB facing up, insert the 6 contacts (short ends) of the header into the plated holes.

4. Holding the header in place with a finger, invert the PCB and place it on the bench top with the head pins resting across the bench. Level the PCB with shims. The head should be fully inserted into the PCB (i.e., plastic body of the header should be in contact with the PCB).



5. Using a loaded solder tip, tack one of the corner pins to its hole. Inspect the header to confirm proper insertion and alignment.

6. While holding a length of solder in the off-hand, apply ample solder to each of the 5 remaining contacts. Solder should form nice cones around each contact.

Main Power Cable

1. Cut 4-inch (10-cm) lengths of 22 or 24 gauge wire, one length with black insulation and one with red insulation. We use lead wires (wire used to make leads for multi-meters, etc.) because of their flexibility.

2. Strip about a 1/8 inch (3 mm) of insulation off each end of the wires.

3. Select 2 male contacts (i.e., needle-shaped) and carefully clamp the needle ends of the contacts to a rigid object to immobilize them during the soldering operation. We use small binder clips to clamp the contacts to a small piece of ¼ inch (6 mm) plywood.

4. Place the bare end of one wire in the solder well of one of the male contact. Hold the bare end in place using a dissection needle held in the off-hand. Solder the wire in place using a loaded iron tip. Allow the solder to set up (cool) before removing the dissection needle.

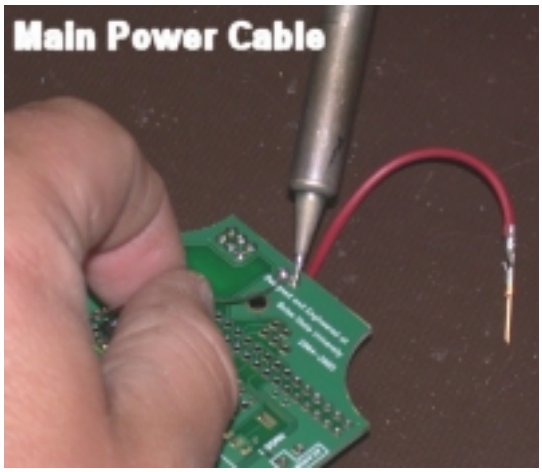
5. Using needle-nosed pliers, clamp the strain-relief tabs of the contact around the wire insulation. Repeat the soldering and strain-relief processes on the remaining contact.

6. Insert the contact bearing the red wire in the hole of the housing marked with an arrowhead. Be certain that the locking tang on the contact is facing up during insertion.

When the contact is completely inserted into the housing, the locking tang should spring up into the locking hole of the housing preventing the contact from being pushed/pulled back out of the housing. You may have to trim the wire insulation slightly (i.e., narrow the diameter slightly) to allow the contact to be completely inserted into the housing. You can use the needle-nosed pliers to carefully and gently grip the needle end of the contact and pull the contact into the housing. With the contact completely inserted, some of the wire insulation and the strain-relief tabs should extend inside the housing.

7. Repeat the contact insertion process for the black wire. This power cable with male connecter should mate properly with the female connector of the D-cell battery. Be certain that the polarity of the two connects are the same (i.e., red wire to red wire and black wire to black wire).

8. With the PCB oriented top-side up, locate the 2 plated holes on the PCB designated for the main power cable (VIN). Insert the remaining bare end of the red wire (i.e., the other end is now attached to the male connector), through the hole marked with a "+".



9. Withdraw the wire from the hole slightly so that some of the bare end is visible between the insulation and the top rim of the hole. Apply liquid flux on the bare wire and down the hole. Using a loaded iron tip, tack the wire in place.

10. Reload the iron tip and touch the tack joint thus adding more solder to the joint. While the solder in the joint is still molten, push the wire back down into the hole so that the insulation is in contact with the top rim of the hole.

11. Repeat this soldering process with the black wire inserted in the hole marked with a "-". Invert the PCB and inspect the 2 plated holes with a portion of the ends of the power cable wires now extending out of them. During the soldering process, solder should have wicked down the holes and pooled around these wire ends. If no solder is visible, carefully hold the affected wire in place (i.e., so the wire does not back out of the hole when the solder is reheated) and apply some solder to the bottom of the hole and the wire ends. When finished the solder should form a nice cone around the wire end. If necessary, repeat for the other wire. Use small side-cutters to cut of any excess bare wire end protruding above the solder joint.

<u>Radio Power Cable</u>

1. Repeat the cable construction process used to build the main power cable (see above) but use female contacts and housing.

2. With the radio power cable constructed, locate the 2 plated holes designated on the PCB for the radio (AC4490). The radio power cable can be mounted on either the top-side or bottom-side of the PCB. We have been mounting it on the top-side as this allows a few more options as to where to position the cable when closing the collar enclosure lid (i.e., as you add accessories to the collars, finding space for cables and connectors becomes challenging). Simply repeat the soldering process used for the main power cable, being certain that the polarity of the connection is correct.

Stereo Jack

1. Apply liquid flux to the 3 pads on the PCB designated for the stereo jack. Place the stereo jack on the PCB and align its 3 contacts with the pads. There is an alignment nub on the bottom of the jack which must be fitted into a hole in the PCB before the jack will seat properly. Consequently, the jack can only be installed one way.

2. Hold the jack in place with a finger on the off-hand and tack one of the 3 contacts using a loaded iron tip.

3. While holding a length of solder in the off-hand to supply ample solder to the joints, solder the remaining 2 contacts being careful to apply most of the heat to the pad rather than the contacts (i.e., these contacts will melt if overheated).

4. Use ample solder to re-solder the tack joint involving the first contact. Inspect the quality of all 3 joints and correct, if necessary.

5. Use alcohol or a flux remover pen to remove all the liquid flux that has accumulated on the PCB. A small brush such as a tooth brush is useful for gentle scrubbing away the flux from the PCB.

6. At this point, it is advisable to configure the GPS receiver (i.e., we set the receiver to operate in “Fix Now” mode to conserve power) or at least confirm that the receiver is operating properly. If the receiver is malfunctioning, it is much easier to remove the GPS at this step. Later the single-board computer will be installed over the GPS and it will have to be de-soldered, with difficulty, from PCB should the GPS be determined to be malfunctioning. A GPS

configuration board is necessary to configure the GPS at this stage of construction. Detailed designs and instructions for constructing the GPS configuration board are available. Alternatively, the GPS can be configured using the single-board computer but only after the computer has been installed.

Reset Button

1. Apply liquid flux to the 4 pads on the PCB designated for the reset button.

2. Place the reset button on the PCB and align the 4 contacts over the pads. This part does not have polarity.

3. Hold the button in place with a finger of the off-hand and tack one of the contacts using a loaded iron tip.

4. Using a length of solder held in the off-hand to supply ample solder to the joints, solder the remaining 3 contacts.

5. Use ample solder to re-solder the tack joint involving the first contact. Inspect the quality of all 4 joints and correct, if necessary.

Transistors (NFET) -- Total of 2

1. Apply liquid flux to the 4 pads on the PCB designated for one of the 2 transistors.

2. Place the transistor on the PCB and align the 4 contacts over the pads. The part can only be properly aligned one way.

3. Hold the part in place using tweezers held in the off-hand and tack one of the contacts with a loaded iron tip.

4. Using a length of solder held in the off-hand to supply ample solder to the joints, solder the remaining 3 contacts.

5. Use ample solder to re-solder the tack joint involving the first contact. Inspect the quality of all 4 joints and correct, if necessary.

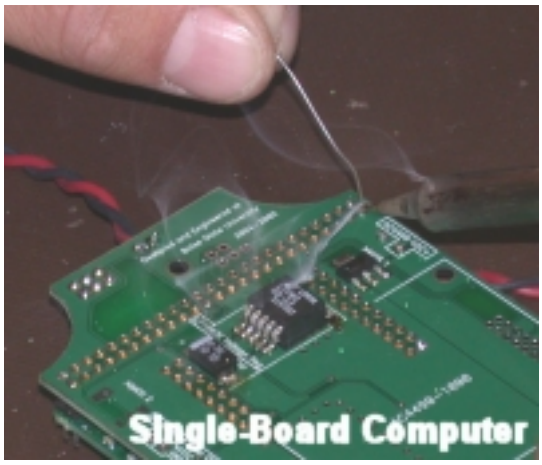
Single-Board Computer

1. Check over the PCB around the GPS receiver and clean off any accumulated liquid flux using alcohol or a flux remover pen. This area of the PCB will be covered by the single-board computer once it is installed, consequently, it will be difficult clean up later.

2. Carefully apply liquid flux to all 90 plated holes on the PCB designated for the single board computer (i.e., CF2). Be certain that the liquid flux goes down into the hole

but avoid getting an excess amount on the PCB surface as it will be difficult to clean up later.

3. With the top-side of the PCB facing up, carefully insert all 90 contacts (pins), distributed on the 3 headers on the bottom-side of the computer, into the plated holes.



4. While holding the computer in place, invert the PCB, rest the top of the computer on the workbench, and adjust the computer so that the ends of the contacts slightly extend beyond the bottom rim of the plated holes. Be certain that the computer is positioned evenly such that all the contacts are protruding from the plated holes an equal amount.

5. Using a loaded iron tip, tack one of the contacts located at one end of the 50-pin header to its plated hole. Move to a contact on the opposite side of the computer from this first contact and tack down this second contact.

6. Holding a length of solder in the off-hand to supply ample solder to the joints, begin soldering all the remaining contacts to their respective holes. Apply heat to both the contacts and holes equally. Use enough solder that it wicks down completely through the hole and forms nice cones around the contact on both the top- and bottom-sides of the PCB. Rotate where you are soldering (i.e., alternate between contacts on opposite sides of the computer while soldering) to avoid heat build up on any particular region of the computer.

7. Re-solder the 2 tack joints and inspect the quality of all 90 joints using a magnifying glass. Use alcohol and a toothbrush to clean off as much of the accumulated liquid flux as possible.

8. Use the white silk-screen legend to locate where the spread spectrum radio (AC4490-1000) transceiver will be installed. Also re-locate the 10 ohm resistor. Apply a single dab of 100% silicon adhesive on the PCB in the center of the edge of the radio legend nearest to the resistor. This dab of silicon will, when cured, serve as spacer to keep the radio from coming in contact with the computer/PCB solder joints. The height of the cured silicon dab should only be about ¼ inch (6 mm) high.

<u>Spread Spectrum Radio Transceiver</u>

1. Although the radio can be configured and tested after it has been installed on the PCB, it is advisable to **plug the radio into a basestation board and configure/test the radio prior to installation**. This approach helps avoid the need to de-solder the radio

(which can be very difficult) should the radio be found to be malfunctioning. Detailed designs and instructions for constructing a basestation board (fixed) are available at: http://clark.nwrc.ars.usda.gov/collars/construct_fixedbasestation.php.

2. Carefully apply liquid flux to all 20 plated holes on the PCB designated for the radio transceiver. Be certain that the liquid flux goes down into the hole but avoid getting an excess amount on the PCB surface as it will be difficult to clean up later.

3. With the PCB position bottom-side up, insert the 20 contacts (pins) of the radio into the plated holes. Holding the radio in place, invert the PCB, rest the bottom of the radio on the workbench, and adjust the radio so that the contacts protrude evenly and slightly above the rim of the plate holes.

4. Using a loaded iron tip, tack one of the contacts on one end to the radio header to its plated hole. Repeat this operation for another contact on the opposite end of the header.

5. Holding a length of solder in the off-hand to supply ample solder to the joints, begin soldering all the remaining contacts to their respective holes. Apply heat to both the contacts and holes equally. Use enough solder that it wicks down completely through the hole and forms nice cones around the contact on both the top- and bottom-sides of the PCB. Rotate where you are soldering (i.e., alternate between contacts on opposite sides of the radio while soldering) to avoid heat build up on any particular region of the radio.

6. Re-solder the 2 tack joints and inspect the quality of all 20 joints using a magnifying glass. Use alcohol and a toothbrush to clean off as much of the accumulated liquid flux as possible. The collar board is now completely assembled and ready for testing and installation inside the collar electronics enclosure.

Assembling the Collar Belting

We use 2 pieces of conveyor belting material, of equal length, to construct one collar. One piece of belting is a brown, urethane-coated polyester belt which is tear- and

abrasion-resistant thus providing durability to the exterior side of the collar. The interior side of the collar is made up of a piece of white, butyl belting which has good flexibility in both extremely low and high temperatures thus reducing neck abrasion. We typical order our belting in 5 cm (2 in) wide rolls (see collar Bill of Materials).

Neck sizes differ among animal species. The length of conveyor belting material used to assemble a collar for a beef cow, consequently, is longer than that used for a mule deer collar. Belting length requirements also vary depending on collar design and how the electronics enclosure (see below) is to be attached to the belting. We make collars for beef cows using 122 cm (48 in) lengths of belting. The belting is attached to the sides of the enclosure. Collars for elk and horses are similar to those of cattle but somewhat shorter. Sheep, goat, and deer collars require 61 cm (24 in) lengths of belting attached to the sides of the enclosure. For our predator collars, we attach the belting to the top of the enclosure similar to the configuration traditionally used in VHF collars. This configuration reduces the collar's vulnerability to chewing. The neck-size adjustment range of the collar is limited, however, because adjustments displace the GPS antenna from the optimum top-center position. Sheep collars can be used on wolves but the tails of the belting should be cut off after adjusting the collar in field to fit the wolf. Cutting off the belting tails give the wolves less to chew on.

Assembling Cattle Collar Belting

The instructions below describe how to assemble the collar belting for cattle collars. The same processes can be used to assemble belting for elk, deer, sheep, goat, and other ungulate collars only the length dimensions of the belting, foam strips, and neck-size adjustment slots will differ. As noted above, belting assembled and configured for goat collars can be used for large predators such as wolves. Instructions for assembling the belting and electronics enclosure for wolf collars, using the more traditional design mentioned above are not currently available.

Laminating and Cutting the Belting

1. We typically have a saddle shop cut our belting to 122 cm (48 in) lengths and laminate the 2 pieces per collar (i.e., 1 urethane piece and 1 butyl piece) using a double row of stitching along all edges of the belting. For cattle collars, we also have the saddle shop cut 2 pairs of adjustment slots in the laminated belting. Each slot should be 10 cm (4 in) long and 6 mm (1/4 in) wide starting 19 mm (3/4 in) from an end of the belting and running parallel to the long axis of the belting. The slots within each pair should be cut parallel to each other, centered within the width of the belting, and separated by 22 mm (7/8 in) on center. Having adjustment slots on both ends of the belting allows the user to make neck size adjustments while still keeping the GPS antenna horizontal in the top-center position (i.e., in the optimum position for GPS signal reception). We take over the assembly process after the belting has been laminated and slots cut.

2. Fold the laminated belting in half length-wise, with the brown urethane-coated piece facing out, and mark the center point of the belting. Center the GPS antenna over this point and draw a short cut-mark, on the belting, where the distal end of the strain-relief (i.e., the flexible plastic cone) of the antenna cable is now positioned (usually about 29 mm [1 1/8 in] from the belting center point). Using a very sharp knife (e.g., a utility knife with new blade), cut a 10-mm (3/8-in) wide slit through **just the top layer of belting (i.e., the urethane-coated piece)** at the cut-mark. This slit should be centered within the width of the belting and run perpendicular to the long axis of the belting. It is

usually easiest to initially cut a smaller slit completely through the top layer of belting and then widen the slit to full width.

3. Turn the belting over, with the white butyl-side up, and locate the end of the belting that is on the **same side** of the belting center point as the slit made above. Make a cut-mark 14 cm (5 1/2 in) from this end of the belting. The cut mark should be about 19 cm (3/4 in) above the interior ends of the adjustment slots. Using a very sharp knife, cut a 10-mm (3/8-in) wide slit through **just the white butyl layer of belting**.

Preparing the GPS Cable

1. The GPS antenna comes standard with a 5-m (16-ft) cable which is much too long for tracking collars. For cattle collars, the cable needs to be shortened to 61 cm (24 in).

2. Use side-cutters to cut the antenna cable to the prescribed length. Slide a 19-cm (3/4-in) length of 6-mm (1/4-in) diameter heat shrink tubing into the cable and then slide it up and out of your way. Slide the crimp sleeve from the MCX connector kit onto the cable and the slide it up and out of your way.

3. Use a very sharp knife or coaxial cable stripper to remove about a 3 mm (1/8 in) length of insulation from the end of the coaxial cable. Loosen the braided wire layer surrounding the core wire of the cable using a dissecting needle or probe. Strip about a 3 mm (1/8 in) length of insulation from the end of the core wire.

4. Slide the body of the MCX connector onto the end of the core wire until the core wire insulation passes inside the connector body and the core wire itself rests against the center post contact of the connector. You may need to trim the core wire slightly to achieve this fit.

5. Using a soldering iron with narrow tip installed, solder the core wire to the center contact of the connector. The easiest way to do this is to load the iron tip with a slight excess of solder then use the tip to apply heat equally to the wire and contact until the solder wicks onto both parts to form the joint.

6. Slide the braided wire down over the insulated core wire and tuck the ends inside the connector. You may have to trim the braided wire slightly to avoid bunching. Slide the crimp sleeve down over the braided wire until the sleeve rests against the connector body. Crimp the sleeve in place using a hand crimping tool loaded with a hexagonal die set designated for MCX connectors.

7. Place the cap over the hole in the connector body and seat the cap in place using a small punch.

Inserting the GPS and Radio Cables

1. To protect the GPS and radio cables from damage, these cables must be inserted through slits previously cut in the belting (see above) and then threaded in between the 2 layers of belting. To do this, a cavity between the belting layers must be created.

2. Place the laminated belting in a bench vise so that the padded jaws of the vise tighten against side edges of the belting causing the 2 layers of belting to separate (i.e., by 1 layer buckling up and 1 layer buckling down) thus forming a cavity. Start forming the cavity near the slit closest to the neck-size adjustment slots (i.e., the second slit).

3. With the cavity formed at this second slit, insert a 10-mm (3/8-in) diameter, hardwood dowel (with the end rounded) into the slit and push dowel between the belting layers and towards the first slit as far as it will easily go. Loosen the vise and reposition the belting between the jaws so that the cavity opens further down towards the first slit. Slide the dowel further in between the belting layers. Repeat the process above until the dowel can be passed through one slit (i.e., near the adjustment slots), between the belting layers, and out the remaining slit (i.e., near the GPS antenna location). New dowels tend to be a bit rough and may be difficult to insert completely. Sanding the dowel with very fine grit sand paper may help. In any case, after some use, the dowel with become polished smooth and easier to insert.

4. Withdraw the end of the dowel back inside the belting and insert the connector end of the GPS antenna cable inside the cavity left between the belting. Slowly withdraw the dowel from between the belting layers while simultaneously threading the antenna cable further down between the layers. Finally, withdraw the dowel completely from the belting and carefully pull the antenna cable (with MCX connector) out the slit nearest the adjustment slots. During the process it may be necessary to reposition the belting in the vise several times to enlarge the cavity between the belting layers. Hold the GPS antenna in its proper position, over the center mark, and continue to pull the antenna cable through the belting layers until all the slack is removed. About 28 cm (11 in) of cable should extend out from the slit in the belting.

5. Position the belting in the vise so that the jaws tighten against the belting edges and open the slit where the GPS cable exits. Insert the blade antenna for the spread spectrum radio transceiver into the slit and carefully push the radio antenna up between the belting layers. Reposition the belting in the vise and use the dowel to carefully push the antenna further up between the belting. Continue this process until the about 28 cm (11 in) of cable with the MMCX connector remain outside of the belting. When completed the radio and GPS antenna cables should extend the same distance outside of the belting.

Constructing the GPS Antenna Cover

1. A durable plastic cover is used to securely mount the GPS antenna onto the collar belting and to protect the antenna from impact damage. It is critical to keep the profile of the covered antenna as low and as stream-lined as possible to avoid having it torn off as the animal moves through heavy brush. **For this procedure you need a wooden mold and a discarded GPS antenna (or a block of wood carved in the shape of a GPS antenna) to form and shape the GPS antenna cover**.

2. Use a band-saw or shears to cut a 15-cm (6-in) by 15-cm (6-in) rectangle of 2.6-mm (1/10-in) thick ABS sheeting.

3. Place the rectangle of sheet in a vented oven which has been preheated to 125 ^{o}C (257 ^{o}F). Allow the sheet to heat until highly pliable.

4. While wear heavy, heat-safe gloves, remove the sheet from the oven, quickly place it in the wooden mold, use the old GPS antenna to press the center of the sheet fully into the cavity in the mold, hold the antenna in place, and use the other hand to smooth out the wrinkles on the remaining portions of the sheet. You will have about 6 seconds of working time to get the GPS antenna properly seated and another 3 to 4 seconds to smooth out the wrinkles. If you run out of time and the sheet stiffens before you finished, place the sheet back in the oven, allow it to reheat, and try the molding process again.

5. Allow the newly-molded cover to cool and stabilize for about 10 seconds. Inspect the cover to be certain the GPS antenna can be seated in the cover such that the bottom surface of the antenna is flush with the bottom of the cover. Make certain the flat portions of the cover are free of wrinkles and that the cover closely follows the curved shape of the mold.

6. Holes for the 4 bolts that attach the antenna cover to the belting are drilled next. The 2 holes on the cable-side of the antenna are to be placed one on either side of the lump formed by the cable strain-relief. These 2 holes should be about 25 mm (1 in) apart and located on the flat portion of the cover but nearly abutting the raised portion (i.e., where the antenna will be housed) of the cover. Mark the centers of these 2 holes with a sharp awl. The remaining 2 holes are to be located on the opposite end of the cover from the first 2 holes. This second set of holes should also be spaced about 25 mm (1 in) apart and should be directly in line, across the cover, with the first set. Mark the location of the second set of holes on the flat portion of the cover such that the holes will nearly abut the raised portion. Use a 4 mm (5/32 in) diameter drill bit to drill all 4 holes.

7. Use a band-saw to carefully trim the cover to 5 cm (2 in) in width by 7.6 cm (3 in) in length. These covers typically are not a uniform product coming out of the mold so, you may have to individually adjust the trim dimensions for each cover

to retain plenty of sheeting material around each of the 4 holes. Use a drum sander to round-off the sharp corners of the cover and smooth and slightly chamfer all of the edges.

8. With the GPS antenna position (i.e., the GPS antenna cable insertion procedure has been completed) in its place on the belting, seat the antenna cover over the antenna and clamp the cover in place using 2 adjustable wood-working clamps. Confirm the cover is positioned correctly with its sides parallel to the sides of the collar belting. Insert the awl in each of the 4 bolt holes in the cover and mark the center of these holes on the belting. Remove the cover from the belting. Make certain that any cables or antennas you have previously inserted into the belting are not in danger of being damaged when these 4 holes are punched through the belting. Use a 4 mm (5/32 in) diameter leather punch and a backing board to punch the 4 holes completely through both layers of the belting.

9. Place the belting on a steady bench with white butyl-side face up. Insert a 6-32 T-nut into one of the holes and seat it in place with a mallet. The teeth of the T-nut should piece the belting. Repeat for the remaining 3 holes.

10. Place the cover over the GPS, align the holes in the cover with the T-nuts passing through the belting, and thread a 13 mm (1/2 in)-long 6-32, machine screw several turns into one of the T-nuts. Repeat for the remaining 3 holes and then firmly tighten each of the machine screws.

Installing the Foam Padding

1. Cut 6-mm (1/4 in) thick, closed-cell foam into a strip 5 cm (2 in) wide by 25 cm (10 in) long.

2. Temporarily mark one side of the strip as the “top”. Bevel both ends of the strip, on the top-side, using fine sandpaper. Also use sandpaper to round over the long edges of the strip but **on the top-side only**. Both sanding operations can be done by hand but a drum sander is much quicker and works quite well.

3. Position the belting on the bench with the GPS antenna and cover down and the white butyl side of the belting up. Place the foam strip on the belting with bottom-side of the foam down against the belting. Center the foam on the belting relative to the belting center mark and the GPS antenna. Make reference marks on the white butyl belting at both ends of the foam strip.

4. Remove the foam strip. Lightly but evenly coat both the bottom-side of the strip and the area of belting between the reference marks with a cryanoacrylate adhesive (i.e., super glue). Align the foam strip over but without touching the belting. This glue grabs instantly and not adjustments can be made once contact is made with the glue on the belting. Starting at one end, apply the foam strip to the belting taking care to keep the foam aligned with the belting edges. When in

completely in place, press the foam strip down firmly against the belting to remove any air pockets and ensure a good bond. Assembly of the collar belting for cattle collars is now complete. Belting assembly for elk, sheep and other ungulate collars differs from cattle collars only in the length dimensions of the belting, foam strips, and neck-size adjustment slots.

Assembling the Collar Electronics Enclosure

We use polycarbonate, water-tight enclosures which consist of a base and a lid portion. The lid has an O-ring seal and is secured to the base using 4 captive screws. We use 2 different sizes of enclosures on our collars. Both sizes of enclosures use the same size bases but the lids differ in depth. The larger enclosure provides more interior space of adding collar accessories (e.g., VHF transmitter and battery). The enclosures and associated hardware (e.g., clamping plate, grommets, ect.) needed to complete the construction of the collar can be found on the collar bill of materials list (see above).

The enclosures can be mounted to the belting portion of the collar in at least 2 configurations. We typically use a side-mount configuration where the 2 ends of the belting are secured to opposite sides of the enclosure using clamping hardware. For predator collars, we have mounted the belting to bottom of the enclosure base (i.e., the enclosure is inverted and the base becomes the top side of the enclosure and the lid becomes the bottom). This top-mount configuration resembles that traditionally used in VHF radio collars. As noted above, use of the top-mount configuration limits the amount of neck size adjustment that can be made without displacing the GPS antenna from the optimum, top-center position on the collar. Consequently, we will present only the procedures for assembling the side-mount enclosure. Because the bases are interchangeable between the 2 different-sized enclosures, the assembly procedures for all of the enclosure bases are the same.

Assembling Side-Mounted Enclosures

Installing the Clamping Plate Hardware

1. Use a small hand-held grinding tool to remove the bump (i.e., in the center of the bottom) from the interior of the enclosure base.

2. On one of the short sides of the enclosure base, drill two 4-mm (5/32-in) diameter holes, 22 mm (7/8 in) apart, centered on the side, and 19 mm (3/4 in) below the lip of the base. Repeat this drilling process on the opposite side of the base (i.e., the other short side).

3. From inside the enclosure base, insert the 2 studs of a clamping bracket through one pair of the drilled holes. The studs should now be extending outside the side of the enclosure base. Inside the enclosure base, draw a mark around the outline of the brass plate portion of the clamping bracket. Remove the clamping bracket from the enclosure. Coat the enclosure wall inside of the marked outline of the clamp plate with 100%

silicone sealant/adhesive. Coat the inside surface of the clamp (i.e., the surface that will be in contact with enclosure wall when the clamping bracket is re-inserted) with the silicone. Be certain to fully coat around the bases of the bracket studs. Re-insert the clamping plate through the enclosure wall. Repeat this coating process for the other pair of holes and clamping plate.

4. From the outside of the enclosure base, coat a portion of the threads on the clamping plate studs with temporary locking compound (e.g., Loctite blue). **Be certain to limit the coating to just the 2-3 threads nears the wall of the enclosure.** Slip a #6 rubber washer onto one of the studs and then thread on a 6-32 stainless steel nut. Tighten the nut until the clamping plate in firmly seated against the enclosure wall. Repeat this fastening process for the other stud. Repeat the entire locking compound coating and fastening processes for the remaining clamping plate.

Installing the Cable-Hole Grommet

1. With the opening of the enclosure base facing up, identify the locator slot on one of the holes used to secure the lid to the base of the enclosure. Diagonally across from the hole with the locator slot should a hole with a locater nub. These locator features allow the lid of the enclosure to be properly seated on the base in only one orientation. The short side of the enclosure bearing the hole with the locator slot will be the "Left" side of the enclosure. Invert the enclosure base. On the bottom exterior of the base, label the appropriate short side of the enclosure as "Left" and the other side as "Right". The remaining 2 sides (i.e., the long sides) are now the "Front" and "Back" sides by default. Locate the 2 lid fastener holes on the left side of the bottom exterior of the enclosure. Mark a line extending from the centers of these 2 holes and parallel with the left side of the enclosure. Using a sharp awl, mark a point on this line which 16 mm (5/8 in) from the lid fastener hole in the left-front position. Drill a 10-mm (3/8-in) diameter hole in the enclosure at this marked point. The hole will be used for inserting the GPS and radio antenna cables and other wiring into the enclosure.

2. Coat the groove of the rubber grommet with 100% silicone sealant/adhesive. Install the grommet in the antenna cable hole and confirm the groove of the grommet is seated properly.

Installing the Foam Padding

1. Cut a 7.6 cm (3 in) x 19 cm (7.5 in) strip from a block of 2.5 cm (1 in) thick, closed-cell foam. Temporarily label one side of the foam strip as the "Top" side and the other as the "Bottom" side.

2. With an enclosure base lying bottom-side up on the bench, center the foam strip (top-side up) over the bottom of the enclosure. The long axis of the foam strip should now be parallel with and centered over the long axis of the enclosure base. Make marks where the bottom side of the foam makes contact with the enclosure (i.e., the marked area should occupy about 7.6 cm (3 in) x 10 cm (4 in) in the center of the foam strip).

3. Identify the marked 7.6 cm (3 in) x 10 cm (4 in) area in the center of the foam strip and leave this area undisturbed. Using a drum sander, bevel the thickness of the foam starting at 2.5 cm (1 in) thick on either side of the marked area and tapering down to 6 mm (1/4 in) thick on the ends of the foam strip. Bevel the width of the foam strip starting at 7.6 cm (3 in) wide on either side of the marked area and tapering down to 5 cm (2 in) on the ends. Invert the foam and carefully round-over all the ends on the top-side of the foam.

4. Make certain that both the bottom side of the foam rectangle and the bottom of the enclosure base are clean. Apply a thin layer of cryanoacrylate adhesive (i.e., super glue) on the area of the foam between you reference marks (i.e., the portion that will be in contact with the enclosure base. Also apply a thin layer of adhesive on the bottom of the enclosure base. Carefully seat the foam on the enclosure base and press into place until fully bonded to the enclosure (usually takes less than 30 seconds). Assembly of the enclosure base is now completed.

Installing the Battery Packs

1. Invert the enclosure lid and position the 2 battery packs (i.e., 1 radio and 1 computer/GPS pack) inside. As noted above, the lids are designed so that they fit on the base in only one orientation. We position the battery packs so that both sets of power supply cables are located on the left side of the lid. We also place the packs so that the capacitors of each pack are facing upward and nearly touching. Battery pack placement for your particular application and collar configuration may require some experimentation. Once in place, take note of the positioning of the packs in the lid and then remove the packs while holding them together. Using electrical tape, tape the 2 pack together, stabilizing them in their current position.

2. Coat the bottom interior of the lid with 100% silicone adhesive but only where the battery packs will be contacting the bottom of the lid when replaced. We use a high peel-strength, RTV silicone adhesive but it is expensive and probably over-kill. Make a good, deep bed of adhesive to seat the packs into. Also coat the surface of the battery packs, where they will contact the bottom of the lid, with the adhesive.

3. Re-position the battery packs inside the lid and firmly press them into the silicone adhesive. Place beads of adhesive along the 2 interior sides of the lid where the packs make contact with the lid. Allow the adhesive to cure for at least 12 hours. The assembly of the electronics enclosure is now complete and ready for the final collar assembly procedures.

Final Collar Assembly Procedures

With the bottom exterior of the enclosure base face up, insert the pair of the clamping plate studs located on the “Left” side of the enclosure through the adjustment slots located on the end of the belting bearing the GPS and radio antenna cables. The studs

should now be extending through the belt from the white butyl side (inside) to the brown urethane side (outside). Place the brass top-plate over the studs. We make our own top plates but the top plates supplied with the clamping plate kits are probably adequate. Thread on the locking nuts to temporarily secure the belting to the enclosure. Repeat this mounting process for the other side of the enclosure and end of the belting. When deploying the collar, you will need to adjust the collar to fit the animal's neck and then completely tighten down the locking nuts to securely clamp the belting in place.

Locate an area on the GPS antenna cable about 7.6 cm (3 in) from the MCX connector. Coat the area with 100% silicone sealant/adhesive. Repeat for the radio antenna cable and any other wiring to be inserted through the cable-hole grommet. Insert the GPS and radio cables and other wiring through the grommet. There should now be about 7.6 cm (3 in) of cable extending inside the enclosure. Seal the cable hole by applying additional silicone to the cable and grommet on both the interior and exterior sides of the enclosure. Allow the silicone sealant/adhesive to cure for at least 12 hours.

Position the enclosure/belting so that the interior of the enclosure is facing up. Hold the collar board held in one hand with the radio side (bottom) facing up. Connect the radio antenna cable to the MMCX connector on the radio. Invert the collar board and place it, top side up, inside the enclosure base. Align the 2 mounting holes on the collar board over the holes in the 2 bosses on the bottom of the enclosure. Be certain the radio antenna cable is located under the board and is not sharply kinked or being pinched between the radio and the enclosure. The GPS antenna cable should extend up through the gap between the collar board and the wall of the enclosure. Connect the GPS antenna cable to the GPS antenna jack connector (MCX) on the collar board. Insert the two PCB mounting screws (included with the enclosure) into the collar board mounting holes and secure the collar board to the enclosure base. The collar is now ready to deploy. Upon deployment, the main and radio power supply cables need to be connected to their respective connectors on the battery packs. While tucking the power cable inside the enclosure, seat the enclosure lid on the base and secure it in place with the 4 lid screws.