Clark ATS+ Collar Construction

Tools and Supplies Required (but not listed in the BOM)

Awl, marking
Board, backing, for leather punch
Bandsaw or jigsaw
Dowel, hardwood, (0.95 cm (3/8-in) dia. by 91.44 cm (36 in) length
Clamps, wood, bar-type (4)
Clamps, small, spring-type (2)
Crimper, sleeve, with 0.128 inch and 0.137 inch hexagonal dies
Crimper, wire, for 22 gauge connectors
Cutter, coaxial cable
File, flat
Fish tape, electricians
Glasses, safety
Gun, heat
Knife, utility
Marker, permanent, black
Multi-meter
Punch, leather, 0.40 cm (5/32 in) dia. hole
Sander, drum
Screwdriver, Phillips, #1
Screwdriver, Phillips, #2
Solder, rosin-core
Soldering iron, adjustable wattage or temperature
Stripper, wire
Tape, labeling
Vise, bench
Vise, soldering

General Soldering Instructions

1. Set the temperature of the soldering iron between 600 to 650 °F. You may need to experiment and adjust your iron temperature to better suit your particular iron, tip, and solder. We have had good success at this temperature using a fine-pointed tip iron with 0.56 mm diameter and a composition of 60% tin/40% lead, 5-core solder.

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

Constructing the Collar Rigging

The Clark ATS+ collar rigging consists of a collar belting assembly and an electronics enclosure. The enclosure is a two-piece, polycarbonate, water-tight box which houses and protects the electronics package of the collar. The belting assembly serves to attach the electronics enclosure around an animal's neck and it also houses and protects the GPS and satellite modem antennas and associated cables. We use two pieces of conveyor belting material, of equal length, to construct one collar belting assembly. 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 5.08 cm (2 in) wide rolls (see collar Bill of Materials [BOM]).

Neck sizes differ among animal species. The length of conveyor belting material used to assemble a collar for cattle, 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 cattle using 106.68 cm (42 in) lengths of belting. Elk/reindeer collars use 73.66 cm (29 in) lengths of belting. Sheep, goat, wolf and deer collars require 60.96 cm (24 in) lengths of belting.

Constructing the Collar Belting Assembly

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 but the length dimensions for the belting, foam strips, and neck-size adjustment will differ.

<u>Preparing the Collar Belting</u>

1. We typically cut our belting to length and then have a saddle shop sew both pieces of belting together (i.e., 1 urethane piece and 1 butyl piece) using a double row of stitching along all edges of the belting, to construct one collar belting laminate. **This double stitching needs to be as close to the edges as possible, to allow room for the neck-size adjustment holes (see below)**. Lightly sand the edges of the belting laminate to round them over and minimize the potential for neck abrasion. Then use a 0.40 cm (5/32 in) dia. leather hole punch and backing board to produce two rows of belt adjustment holes in each end of the belting laminate. The rows should run parallel to the long axis of the belting thus forming 10 pairs of holes perpendicular to this axis at each end of the belting. The holes within each pair should be centered within the width of the belting and separated by 2.22 cm (7/8 in) on-center. The first pair of holes should be 1.91cm (3/4 in) from the end of the belting, the nine remaining pairs of holes should be punched 1.27 cm (1/2 in) from each other; working your way towards the center of the collar. Having adjustment holes on both ends of the belting allows the user to make neck size adjustments while still keeping the GPS and satellite modem antennas horizontal in the top-center position (i.e., in the optimum position for RF signal reception).

2. Fold the belting laminate in half length-wise, with the brown urethane-coated piece facing out, and mark the center point of the belting. Then draw a short mark on the belting about 5.08 cm (2 in) from the belting center point. If you are using a GPS antenna different from that listed in the BOM, position the GPS antenna on the belting with the distal end of the antenna (i.e., end opposite the cable) lined up over the center point mark on the belting and place the short mark where the antenna cable can be pushed against the belting without creating a sharp bend in the belting, this is usually about 0.64 to 1.27 cm (¼ to ½ in) from the antenna. For GPS antennas equipped with strain-relief on the antenna cable place the short mark near the distal end of the strain-relief.

3. Using a very sharp knife (e.g., a utility knife with new blade), cut a 1.91 cm (3/4-in) wide slit through **just the top layer of belting (i.e., the brown, urethane-coated piece)** at the short 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. Once the slit has been cut, use the leather punch to punch holes on each end of the slit, **only punching through the top (brown colored) layer**, to prevent any further splitting of the belt.

4. 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 mark 2.54 cm (1 in) above the 10th pair of adjustment holes. Cut a slit at the mark but **only cut through the white butyl layer of belting**. This slit should be centered, 1.91 cm (3/4 in) long, and run perpendicular to the long axis of the belting. Then use the leather punch, in the same way as above, to stop splitting but **only punch through the white butyl layer.**

<u>Threading the GPS and Satellite Modem Antenna Cables</u>

1. Both the GPS and satellite modem antennas come standard with cables which are much too long for tracking collars. Determine the length of cable needed by positioning one of either of the antennas centered over the belting center-point mark. Straighten and pull the cable tight and parallel to the belting length. Cut the cable at a point where it extends 30.48 cm (12 in) past the end of the belting. Cut the cable for the remaining antenna to the same overall length as the first cable.

2. To protect the GPS and satellite modem antenna cables from damage during deployment on animals, these cables must be inserted through the slit cut in brown, urethane-coated layer of the belting laminate, threaded in between the two layers of belting, and exiting through the slit cut in the white butyl layer of belting. Threading is done by first creating a cavity between the belting layers. Place the belting laminate in a bench vise, white butyl side up, so that the jaws of the vise tighten against the side edges of the belting, causing the two layers of belting to separate (i.e., by one layer buckling up and one layer buckling down) thus forming a cavity. Start by forming this cavity near the slit previously cut in the white butyl layer. Getting the belting layers to separate and form a proper cavity takes some trial and error but usually gets easier as the belting gets

more supple with repeated handling and adjustment in the vise. Warming the belting laminate to 27 to 32° C (80 to 90°F) can also help make forming the cavity easier.

3. Prepare a 0.95 cm (3/8-in) diameter hardwood dowel about 91.44 cm (36 in) length by rounding over both ends of the dowel, eliminating sharp edges or corners, and thus forming domed rather than pointed or squared-off dowel ends. Insert one end of the dowel into the slit in the white butyl belting layer and push the dowel between the belting layers and towards the second 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 slit in the brown, urethane-coated layer of belting. Slide the dowel further in between the belting layers. Repeat the process above until the dowel can be passed through one slit and exit out the other slit. New dowels tend to be a bit rough and may be difficult to insert completely. Polishing the dowel with very fine steel wool and then applying a light coat of wax or non-corrosive dry lubricant (e.g., furniture polish) can help make dowel insertion easier.

4. With the belting laminate still firmly clamped in the bench vise, withdraw the dowel completely from the belting cavity and insert an electrician's fish tape into the slit in the white butyl layer. Push fish tape through the cavity in the belting until it exits the slit in the brown, urethane-coated layer. Thread the ends of both antenna cables through the hole in the fish tape (i.e. like threading a needle with two threads). The short ends or tails of the cables should extend about 2.54 cm (1 in) from the fish tape. Fold these tails back, parallel along the long end of the cable, and secure them in place with a few wraps of electrical tape. Using one hand, slowly withdraw the fish tape down through the belting layers, while simultaneously straightening and threading the antenna cables with the other hand. Finally, withdraw the fish tape completely from the belting and carefully pull the antenna cables out the slit in the white butyl belting layer. During this cable fishing process it may be necessary to reposition the belting in the vise several times to enlarge the cavity at different points along the length of the belting laminate. Continue to pull the antenna cables through the belting layers until the GPS antenna is in its proper position (i.e., distal end lined up with the belting center mark) and the satellite modem antenna is on the opposite side of the center mark from the GPS antenna and the proximal end of the satellite modem antenna is about 1.27 cm (½ in) from this mark. While holding the antennas in these positions, gentle tug the cables to ensure all the slack is completely removed. About 30.48 cm (12 in) of GPS antenna cable and about 25.40 cm (10 in) of the satellite modem antenna cable should now extend out beyond the end of the belting. Using labeling tape, label the respective cables, with the names "GPS" and "SAT", near where they exit the slit in the white butyl belting.

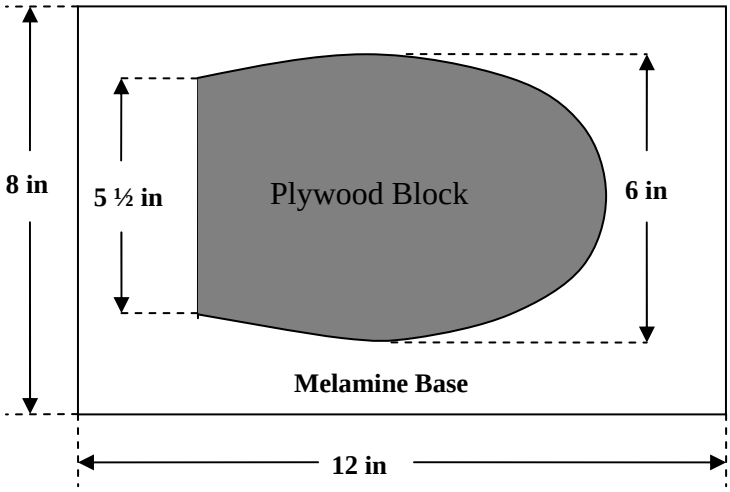
Constructing the Antenna Cover

The antenna cover is made from the same brown, urethane-coated belting as the belting laminate. The cover is secured in place using two clamping brackets, each with a pair of 1.91 cm (¾ in) long, threaded studs. The GPS and satellite modem antennas are contained within the space formed between the cover and belting laminate and the voids within this space are later filled with a polyurethane potting compound. The length of the

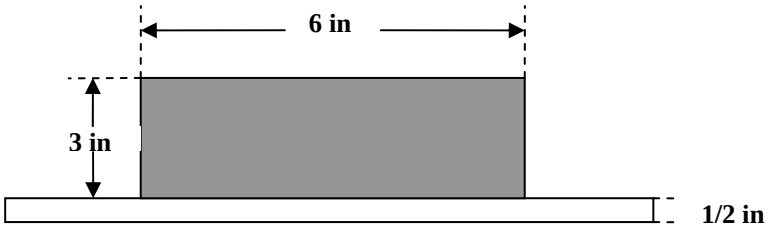
belting used in making the cover depends the size of the actual antennas used. The cover for the GPS and satellite modem antennas included in the BOM should be 19.05 cm (7 ½ in) long. When determining the length of the cover, keep in mind you want the shortest possible cover length given the constraints of antenna size and curvature of the collar when placed in the wooden form used to pot the antennas in polyurethane (see below). In determining the cover length, you are aiming to produce the lightest and lowest profile antenna assembly possible thus reducing its likelihood of being snagged in brush or struck and damaged against overhanging structures.

Antenna Potting Form
(Not drawn to scale)

Top View



Side View



1. Using a 0.40 cm (5/32 in) leather hole punch and backing board, punch a pair of holes about 1.27 cm (½ in) from each end of the antenna cover piece. As with the neck adjustment hole-pairs described above, the holes within each pair should be centered within the width of the belting and separated by 2.22 cm (7/8 in) on-center.

2. Now determine where the two corresponding pairs of cover-mounting holes should be punched through the collar belting laminate. When using the antennas listed in the BOM, we draw a line 5.72 cm (2 ¼ in) from the center point of the belting laminate

and another line this same distance on the opposite side of the center point. We then center one end of the cover piece on the belting laminate so the pair of holes in the cover is centered on the corresponding marker line on the laminate Small spring clamps can be useful for temporally holding the end of the cover piece in place once it has been correctly positioned on the belting laminate. Pass the leather punch through the cover piece and lightly mark the hole locations on the belting laminate by tapping on the leather punch. Remove the cover from the belting laminate and inspect the marked hole locations to confirm cables, etc. will not be cut or damaged if holes are punched at these two locations. After inspection and confirmation, punch the pair of holes completely through the belting laminate. Mark the locations for the other pair of holes, inspect and confirm, and then also punch these holes completely through the belting laminate.

3. Install two clamping brackets, each with a pair of 1.91 cm (¾ in) long, threaded studs by insert the studs through the corresponding holes in the belting laminate, starting from the white butyl side of the laminate. Position the cover piece over the antennas and thread the studs, now protruding through the belting laminate, through the corresponding holes in the cover piece. Install a brass clamp plate over each pair of studs. Install and tighten the #6-32 locknuts on the studs to secure the cover to the belting laminate. The brass clamp plate used on the cable side of the belting laminate should be slightly bent in the middle to avoid crimping or damaging the antenna cables inside the belting laminate when the clamping bracket is tightened.

4. If you use antennas which are different from those listed in the BOM, the cover piece may have to be a different length than the one described above. In addition, the cover-mounting holes may also need to be punched in different locations than those described. For the holes to be punched on the cable side of the belting center point, be sure to give enough space to accommodate the antennas and cables while allowing the end of the cover to sit flush on the belting laminate when the bracket is tightened. On the opposite side of the center point, punch the cover-mounting holes as close to the antenna as possible while still allowing the end of the cover to sit flush on the belting laminate.

5. The next step is to secure and protect the antennas from moisture and impact damage by potting them in polyurethane. A wooden form is used in this process to shape the collar belting so it conforms to the curvature of an animal's neck. The form is built from a block of wood or several pieces of plywood screwed together to obtain the appropriate dimensions. For most medium (e.g., deer) to large animals (e.g., beef cattle), a block about 7.62 cm (3 in) tall, 14.61 cm (5 ¾ in) wide and 15.24 cm (6 in) long works well. Using a bandsaw, cut the block of wood into the shape illustrated in the dimensional drawing (see below). Curvature of the form is based on a circle with a 7.62 cm (3 in) radius. Center and attach the block of wood on a piece of 1.27 cm (½ in) melamine-sheathed particle board using wood screws. The melamine sheathing is needed so that the polyurethane will not stick to the base of the form.

6. Lay the collar belting on its side and loosely wrap it around the wooden block with the antenna cavity positioned opposite the flat side of the block. Apply a bead of general purpose silicone sealant on the form base board between the wooden block and

the antenna cavity in the belting. Use wood clamps to clamp the ends of the collar belting together thus tightening the belting around the wooden block. Firmly press the edge of the belting down against the base of the form allowing the bead of sealant to create a seal between form base and the inner part of the antenna cavity of the belting. Use the sealant to create another seal between form base and around the outside of the antenna cavity. You have now formed a 3-sided mold to hold the polyurethane potting compound. Allow the sealant to dry at least 2 hours before proceeding to the next step of pouring the polyurethane.

7. The polyurethane specified in the BOM comes as a 2-part compound which must be measured and mixed prior to pouring into the mold. **Follow the manufacturer's directions for mixing the polyurethane.** We use a laboratory balance to pour out the needed proportions (by mass) of each of the 2 parts. For a single mold, we use 45 g (1.59 oz) of Part A and 20 g (0.705 oz) of Part B for a total of 65 g (2.29 oz) of polyurethane. Your total mass of polyurethane needed for each antenna potting mold may differ depending on the size of antennas and antenna cover used. If pouring multiple molds, mix only enough polyurethane for a 3-5 molds at a time; otherwise the urethane may start to harden and not pour as easily. Allow the polyurethane to dry and cure in the molds at least overnight. **Follow the manufacturer's directions for the specific drying and curing times required under your climatic conditions.**

Constructing the Collar Electronics Enclosure

A 2-piece, polycarbonate, water-tight enclosure (i.e., IP66/IP67) consisting of a base and a lid portion is used to contain and protect the electronics package of the collar from moisture, dust, and impact damage. The base portion of the enclosure receives the clamping brackets for mounting the enclosure to the collar belting and the cable glands to seal around the antenna cables where they enter the enclosure. The lid portion has an O-ring seal and is secured to the base using four captive screws. Be aware that 2 different lid sizes are available for this enclosure, make sure you use the part number in the BOM and get the enclosure lid that is 85 mm (3.3 in) in depth.

<u>Installing the Clamping Bracket Hardware</u>

1. 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 12.7 mm (1/2 in) below the lip of the base. Repeat this drilling process on the opposite, short side of the base.

2. Select a clamping bracket, with 2.54 cm (1 in) long studs and apply a bead of general purpose silicone sealant completely around the base of each stud. From inside the enclosure base, insert the clamping bracket studs through the enclosure wall. Firmly press the bracket outward until the studs fully protrude outside the enclosure and the clamping plate is flush with the enclosure wall. Repeat this bracket sealing and insertion process on the opposite of the enclosure.

3. Locate a pair of clamp bracket studs now protruding from the outside of the enclosure base. On the studs, coat the 2 or 3 threads nearest the enclosure wall with permanent locking compound (e.g., Loctite red). **Be certain to limit the coating to just these 2-3 threads nearest the wall of the enclosure.** Thread on a #6-32 stainless steel nut on each stud and tighten the nuts until the clamp plates are firmly seated against the inside walls of the enclosure. Wipe up any excess sealant that has squeezed out when the clamp plate is tightened. Repeat these thread-locking and fastening processes for the remaining clamping bracket.

4. Secure the enclosure base to the collar belting assembly by inverting the base (i.e., bottom-side up) and inserting the studs from the enclosure through the bottom-most hole pair on each, respective end of the belting assembly. Slide a brass clamp plate over a stud pair, then thread #6-32 locknuts (i.e., Nylock nuts) on to each stud of the pair. Repeat this process for the other pair of studs. Use a nutdriver to snuggly tighten both locknuts on the cable-side of the belting assembly. Snuggly tighten only one of the locknuts for studs on the opposite side of the belting assembly, leave the other locknut only hand tightened.

Installing the Cable Glands

1. Two cable glands are needed to provide water-tight entrances for the GPS and satellite modem antenna cables into the enclosure. First, find the bottom-exterior side of the enclosure base and locate the end of this side bearing the label “60” (i.e., the label indicating the 60 mm width of the enclosure base). Invert the base and find the screw boss on this end of the bottom-interior side of the base. The screw boss has two buttresses that project laterally out from the central portion of the boss. Remove a lock nut off a cable gland and place the nut adjacent to the right side of the screw boss and between the boss and the interior wall of the enclosure base. Rotate the nut, if necessary, so that one point of the nut fits snuggly into the corner formed by the right buttress and central portion of the screw boss. Trace the hole in the nut onto the enclosure base using a marker. Then mark the center point of the hole trace. Note that positioning the locknut in this fashion is intended to prevent the lock nut from turning when the cable gland is inserted through a drilled hole and threaded on to the nut. Repeat this process for a nut position on the left side of the screw boss.

2. Carefully centerpunch and drill a 0.60 cm (15/64 in) dia. hole at each hole center mark.

3. Apply a small drop of permanent threadlock compound to the threads of a cable gland locknut. Place the locknut in place, inside the enclosure and centered over drilled hole on the right side of the screw boss. While holding the locknut in position, thread a cable gland, from the outside of the enclosure, through the relevant drilled hole, and onto the locknut. Tighten the locknut with a nutdriver until snug and the o-ring on the gland forms a seal with the exterior of the enclosure. Using a marker write “GPS” near this installed cable gland, on both the interior and exterior sides of the enclosure. Repeat this

thread-lock, installation, and marking process for the remaining cable gland. Label this left-side gland with “SAT” for the satellite modem antenna cable.

Inserting and Adjusting the Antenna Cables

1. Cut a 17.78 cm (7 in) length of braided cable sheathing and slightly melt both cut ends of the sheathing with a heat gun to prevent the sheathing from unraveling. Insert the end of one of the antenna cables through the sheathing. Slide the sheathing up the cable and compress the sheathing against the collar belting where the cable exits the slit in the belting. Temporarily secure the sheathing in place with a small spring clamp. Repeat this sheathing process for the other cable.

2. Remove the cap from the “GPS” cable gland, then remove the bead-like, rubber gland seal from the cap. Starting from the dome-side of the cap, insert the end of the GPS antenna cable through the cap and slide the cap up along the cable and out of the way. Insert the cable through the gland seal and slide the seal up next to the cap. Insert about 10.16 cm (4 in) of the cable through the hole in the body of the cable gland and into the enclosure. Slide the gland seal and cap down to the cable gland body and loosely thread the cap back onto the body. Repeat this insertion and threading process for the satellite antenna gland and cable. Confirm that both antenna cables can easily slide back and forth through their respective cable glands. If not, loosen the cap on the cable gland to loosen the constriction around the cable. Remove the clamps from the cable sheathing.

3. Sit in a chair and place the collar, standing upright, in your lap and the ends of the antenna cables hanging freely from inside the enclosure. Use one hand to slowly press down on the top of the antenna cover assembly thus forcing the collar belting to buckle outward on both sides of the collar. Use the other hand as necessary to feed slack, upward through the cable glands, to relieve any tension that develops on the span of cable between the glands and the slit in the belting. Continue this process until the antenna cover has been pressed down to the enclosure. Pull any slack in the cables back down through the cable glands, then feed about 2.54 cm (1 in) of slack up through the cable glands. The gland-to-slit span of both cables should no longer be under tension. Tighten the caps of both cable glands but **do not over-tighten.** The caps should be tight enough to form a watertight seal and keep the cables from sliding in/out through the glands but not so tight as to damage or crimp the cables. Release the antenna cover and then double-check the cables cannot be put under tension by deforming the shape of the collar belting. The purpose of this cable length-adjustment process is to prevent damage to the antenna cables when the collar is momentarily snagged in brush or tree limbs by the animal thus deforming the shape of the collar. This process puts enough slack in the cables such that, even when the collar has been sized to its largest neck-size adjustment holes, the cables cannot be tension-damaged by collar deformation.

4. Loosely install a cable tie around the upper end of one of the cable sheathings. Slide the sheathing up the cable until the upper end meets the slit where the cable exits the belting. Tighten the cable tie until the upper end of the sheathing is firmly secured to

the cable and will not slip up/down along the cable. Repeat with the other cable and sheathing.

5. Position the collar belting in a belt vise so that the slit where the antenna cables exit the belting is between the vise jaws. Compress the belting to open the slit slightly. Use your finger or end of the hardwood dowel (described in the "Preparing the GPS and Satellite Modem Antenna Cables" section above) to push the upper ends of the cable sheathings and the cable ties inside the slit. Remove the belting from the vise.

6. Loosely install a cable tie around the lower end of one of the cable sheathings. Slide the sheathing down the cable until the lower end expands and engulfs the cable gland. Slide the cable tie down over cap of the cable gland which, is now inside the sheathing, and tight the cable tie so that the sheathing will not slip off the cable gland. Repeat this process for the other cable sheathing.

7. Insert the conic tip of a tube of silicone adhesive (RTV-167) in one side of the slit in the belting and apply a liberal amount of adhesive inside the belting around the cable sheathing and cable tie inside the slit. Repeat on the opposite side of the slit, around the other cable sheathing and cable tie. Application of this adhesive is intended to secure the upper end of the cable sheathings inside the slit in the belting.

8. Use your fingers to locate the cap on top of one of the cable glands within the lower end of the sheathing. Press the tip of the silicone adhesive tube against the sheathing at the point where the cable enters the cap of the cable gland. Squirt the silicone adhesive through the sheathing and form a cylinder of silicone over the cap and up the cable above 2.54 cm (1 in). Repeat for the other cable gland.

9. Starting where the lower end of the sheathing contacts the enclosure base, apply a heavy bead of silicone adhesive completely around the outside of each cable sheath. Apply a second and third bead of silicone around each sheathing, building a bead on top of previous bead until you form two silicone cylinders about 7.62 cm (3 in) tall. Join the two cylinders by squirting a bead of silicone between the cylinders and build this juncture up to about 3.81 cm (1 ½ in) tall. Smooth any irregularities and fill any gaps or holes in the silicone using a small spatula or wooden tongue depressor. What you have just sculptured is a silicone strain-relief for the antenna cables which encapsulates the cable glands and the lower 7.62 cm (3 in) of the cable sheathing. Once dried and fully cured this strain-relief will protect the cables from flexure damage at the point where the cables exit the cable glands. Note that we have tried commercially-supplied, strain-relief cones but this shop-built solution seems to work best for this application.

Attaching the GPS Antenna Connector

1. Pull the end of the GPS antenna cable straight out from the open enclosure base. Measure the cable from the lip of the enclosure base to a point 10.16 cm (4 in) up towards the end of the cable. Place a cut mark at this point. Use coaxial cable cutters to cleanly cut the antenna cable at the cut mark. It may be helpful to refer to the connector

data sheet (http://www.linxtechnologies.com/resources/diagrams/conmmcx007.pdf) during the following instruction steps.

2. Open the MMCX plug connector kit and thread the brass tube and piece of heat shrink provided onto the cable and slide them up and out of the way.

3. Carefully cut away a 1.07 cm (0.421 in) length of the black insulation from the end of the GPS antenna cable. **You want to avoid cutting into the wire braiding underneath the black insulation.** Pull back the wire braiding to expose the aluminum foil sheathing. Find the split in the sheathing and pull the sheathing back and off of the insulated center conductor wire underneath. Cut the sheath off the close to where it emerges from under the black outer insulation of the coax. Carefully cut away a 0.23 cm (0.091 in) length from the tip of the white or clear center conductor insulation. **You want to avoid cutting into the stranded copper, center conductor wire underneath the insulation**.

4. If necessary, straighten and re-twist the exposed strands of center conductor wire. Remove the pin from the connector kit and check that the exposed center conductor wire will fit inside the recess in the end of the pin. Double-check to make sure all the strands of the wire are going inside the recess. After this dry fit test remove the wire from the pin and carefully cramp the insulated portion of the wire in a soldering vise.

5. Using a soldering iron, very lightly tin the exposed center conductor wire; making sure to draw the solder on the tip of the wire out to a fine point. Remove the wire from the soldering vise.

6. Place the connector pin on a flat piece of wood such as 5.08 cm by 5.08 cm (2 in by 2 in) piece of 0.64 cm (¼ in) thick plywood. Use tweezers to rotate the pin until the hole in the side of the pin is facing up. Position the pin so that open end of the pin is slightly overhanging an edge of the wood. Holding the soldering iron nearly horizontal place the tip of the iron on top of the hole in the pin thus holding the pin in place with the iron. Allow the iron to heat the pin for a few seconds. Reinsert the exposed, tinned center conductor wire completely into the recess of the pin. You may have to wait a moment for the heated pin to melt the solder on the wire before the wire can be completely inserted. Quickly remove the soldering iron from the pin to avoid melting or deforming the insulation on the center conductor wire. Allow the pin to cool for about 10-15 seconds. Give the pin a slight tug to confirm that it has been well-soldered to the center conductor wire. If any solder has oozed out the hole in the pin, lightly scrap off the solder with the blade of a craft or utility knife.

7. Insert the pin through the rear of the connector body and push the pin forward until the point of the pin is even with the front end of the connector body. If you have difficulty with completely inserting the pin into the connector body, remove the pin and check for excess solder on the sides of the pin. This is intended to be a tight fit so, it does not take much excess solder to cause an insertion problem.

8. Push the wire braiding up over the connector body. Make sure the braiding is evenly distributed around the circumference of the connector body. Use a small pair of sidecutters, trim the wire braiding so that it is even with the rear end of the main portion of the connector body, i.e., even with the juncture between the main and rear tube portions of the body. Use a multimeter to check that there is the correct level of resistance (i.e., no shorting) between the connector body/wire braiding and the center pin. The actual resistance measured will vary with the make/model of the antenna used. When using the GPS antenna listed in the BOM, we typical see a resistance of about 550 ± 30 Kohms. A dead short will read 0 to 0.5 Ohms depending on the multimeter and resistance in its cables.

9. Slide the brass tube, which was previously placed on the cable, up and completely over the braiding. The brass tube should now be flush with the main portion of the connector. Use a hexagonal crimping tool with a 0.348 cm (0.137 in) die to crimp the round brass tube into a hexagonal tube around the shaft of the connector. Slide the heat shrink up over the crimped tube and heat with a heat gun to shrink into place.

Attaching the Satellite Modem Antenna Connector

1. Pull the end of the satellite modem antenna cable straight out from the open enclosure base. Measure the cable from the lip of the enclosure base to a point 10.16 cm (4 in) up towards the end of the cable. Place a cut mark at this point. Use coaxial cable cutters to cleanly cut the antenna cable at the cut mark. It may be helpful to refer to the data sheet (http://www.linxtechnologies.com/resources/diagrams/consma012.pdf) during the following instruction steps.

2. Open the SMA R/A plug connector kit and thread the brass tube and piece of heat shrink provided onto the cable and slide them up and out of the way.

3. Carefully cut away a 1.05 cm (0.413 in) length of the black insulation from the end of the antenna cable. **You want to avoid cutting into the wire braiding underneath the black insulation.** Pull back the wire braiding to expose the aluminum foil sheathing. Find the split in the sheathing and pull the sheathing back and off of the insulated center conductor wire underneath. Cut the sheath off the close to where it emerges from under the black outer insulation of the coax. Carefully cut away a 0.25 cm (0.098 in) length from the tip of the white or clear center conductor insulation. **You want to avoid cutting into the stranded copper, center conductor wire underneath the insulation**.

2. If necessary, straighten and re-twist the exposed strands of center conductor wire. Now bend the exposed wire upwards slightly without disturbing the twist in the strands. Carefully cramp the insulated portion of the wire in a soldering vise.

3. Using a soldering iron, very lightly tin the exposed center conductor wire. Allow the solder to cool for 10-15 sec. Remove the wire from the soldering vise.

4. Place the SMA connector body in a soldering vise with the hexagonal, nut-like end facing down and the access opening in the main body of the connector facing up. While watching through the access opening, insert the antenna cable into the tubular portion of the connector and push forward until the tinned center conductor wire is fully seated in the groove on the end of the center pin mounted inside the connector body. You may need to guide the tinned end of the wire into the groove with the tip of a craft knife blade. If the slot in the pin is misaligned with the cable entrance in the connector, use the tip of the craft knife or a very small slotted screwdriver to turn the pin for proper alignment. You may also need to press down on the tip of the tinned wire to get it to fully seat inside the groove.

5. Holding the soldering iron vertical, carefully heat the connector center pin then apply a light coat of solder to the pin and the tinned coax wire. **Be very careful not to overheat the coax and melt its insulation. In addition, be very careful not to get any solder on the inside of the connector body** which would cause shorting or make it difficult to apply the seal to the connector (see below). Use a magnifying glass to check for stray wire strands or debris inside the connector body which could cause shorting between the connector body and the center pin. Depending on the antenna actually used, a satellite modem antenna may have such low resistance between conductor and ground plane that is difficult to detect a true short between the connector body and the center pin using a multimeter.

6. Using tweezers remove the white insulating cap from the connector kit and place it horizontally over the top of the center pin. Next place the brass sealing cap over the insulating cap. The brass cap will not quite fit into the circular groove just inside the opening in the connector body. Confirm the connector body is tightly clamped in the soldering vise. Use a punch of the same diameter as the brass cap to seat the cap into place in the groove with a couple of light taps with a small hammer. Remove the connector from the soldering vise.

7. Push the wire braiding up over the tubular portion of the connector body. Make sure the braiding is evenly distributed around the circumference of the connector body. Use a small pair of sidecutters, trim the wire braiding so that it is even with the main portion of the connector body, i.e., even with the juncture between the main and tubular portions of the body. Slide the brass tube, which was previously placed on the cable, up and completely over the braiding. The end of the brass tube should now be flush with the main portion of the connector. Use a hexagonal crimping tool with a 0.325 cm (0.128 in) die to crimp the round brass tube into a hexagonal tube around the shaft of the connector. Slide the heat shrink up over the crimped tube and heat with a heat gun to shrink into place.

<u>Constructing the Cable Sleeve</u>

A cable sleeve is required to protect both the cables and the animal's neck from wear. The sleeve also helps prevent the cables from getting snagged on brush and tree branches as the animal moves through its habitat. A sleeve which is closed on the top but open on

the bottom is used for these functions because it provides a cavity space for the cables to be pushed further into when the collar is adjusted to fit a smaller neck circumference. The sleeve is made from three types of tape; bidirectional-filament strapping tape (i.e., a highly tear-resistant strapping tape for heavy duty package sealing); heavy-duty, ultraviolet light (UV) resistant duct tape; and regular, inexpensive duct tape. The three types of tape should be 4.76 cm (1 7/8 in) to 5.08 cm (2 in) in width.

1. The length of the sleeve will depend on the size of the collar. For a cow collar, the sleeve will need to be 17.78 cm (7 in) long. Measure out a 35.56 cm (14 in) length of the regular duct tape and then carefully fold the tape in half, sticky side to stick side. Measure out another 35.56 cm (14 in) length and position the first, folded piece of tape onto this second piece of tape, aligning one end of each piece, and laterally offsetting the pieces by 3.18 cm (1 ¼ in). Fold the remaining 17.78 cm (7 in) of the second piece over the first piece. You have now created a piece of duct tape cloth which is about 6.35 cm (2 ½ in) wide and 17.78 cm (7 in) long.

2. Position the tape cloth along the belting so that it covers the antenna cables and cable glands and allows about 6.35 cm (2 ½ in) of cavity space above the slit in the belting where the cables exit. Select the bidirectional filament strapping tape and horizontally wrap a 13.97 to 15.24 cm (5 ½ to 6 in) piece around the belting thus securing the top end of the tape cloth in position. Add wraps of strapping tape as you move down the belting towards the enclosure. Use three pieces total of strapping tape, with about (1/4 in) overlap, to make one layer of wrapping. The wrapping should end about 3.81 cm (1 ½ in) above the enclosure, leaving the bottom portion of the tape cloth unwrapped. As you apply the last wrap of strapping tape you will likely need to form an S-shaped bend in the antenna cables so that they fit under the tape cloth and the strapping tape does not adhere to the cables. Apply two more layers of strapping tape in the same manner as above. You have now created a highly tear-resistant sleeve which contains and protects the antenna cables but still allows some neck-size adjustment on the cable-side of the collar. This sleeve is, however, highly susceptible to UV damage.

3. Select the UV-resistant duct tape and apply four layers of this tape to finish the sleeve. When applying the last layer of this duct tape, make sure that the end of each length of tape or wrap finishes on the inside of the collar, i.e., next to the animal's neck. By finishing on the inside, the tape ends are less likely to become unstuck as the animal rubs against brush and trees.

<u>Padding the Collar Belting</u>

1. Using a utility knife and a ruler, 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 a drum sander. Round over the long edges of the foam strip with the sander but **only on the top-side**. Both sanding operations can be done by hand but a drum sander is much quicker and works quite well.

3. Lay the collar on its side. Place the foam strip on the belting with the bottom-side of the foam against the inside of the belting. Center the foam along 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 the bottom-side of the foam strip with a cryanoacrylate adhesive (i.e., super glue). Align the foam strip between the marks on the belting. This glue grabs instantly and adjustments can be hard to make once contact is made with the belting. Consequently, this procedure is most successful if you start at one end, apply the foam strip to the belting gradually, and take care to keep the foam aligned with the belting edges. When completely in place, press the foam strip down firmly against the belting to remove any air pockets and ensure a good distribution of the glue. **Immediately wipe up any excess glue that oozes out.** Select a scrap piece of belting about the size of the foam strip, place it on top of the foam, then use 4 equally spaced wood clamps to compress and hold the foam in place. **Again, immediately wipe up any excess glue that oozes out.** Allow the glue to set for about 15 min before removing the clamps. If you have trouble getting a complete, even bond between the foam and belting, try using a short piece of 15.24 cm (6 in) diameter plastic pipe rather than the scrap belting for a clamping surface.

Padding the Electronics Enclosure

1. Using a bandsaw, cut a 7.62 cm (3 in) x 20.32 cm (8 in) strip from a block of 2.54 cm (1 in) thick foam. Temporarily label one side of the foam strip as the “Top” side and the other as the “Bottom” side. Refer to the diagram below to properly shape the foam by making additional bandsaw cuts.

2. Position the foam, bottom-side down, and centered on top of the enclosure base. Index this position by placing a mark on the side of the foam and a corresponding mark on the side of the enclosure.

3. While still holding the foam in position, mark on the foam, the area where the foam meets the lump formed by the silicone strain-relief for the cable glands.

4. Remove the foam and use a utility knife, set for a 1.27 cm (1/2 in) cutting depth, to cut out a shallow cavity to accommodate the cable-gland lump.

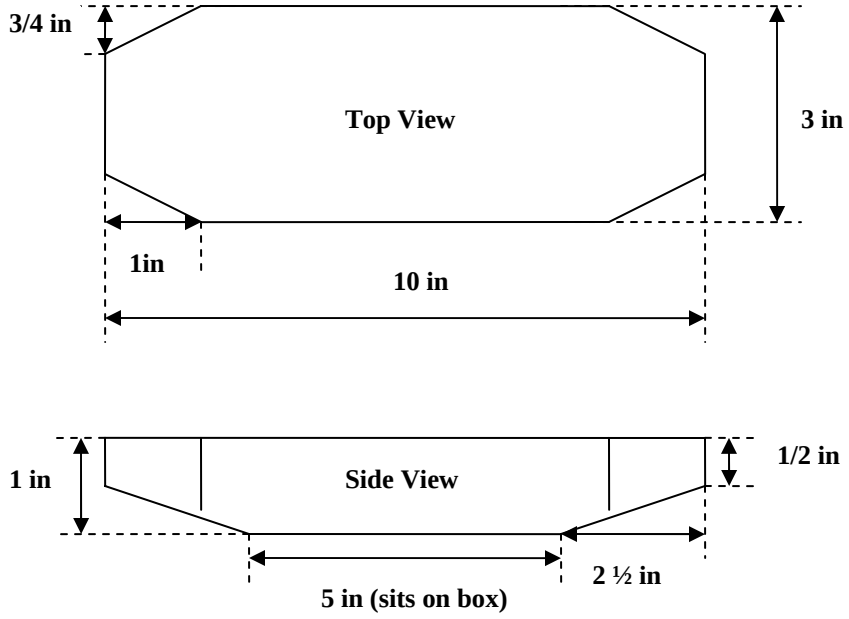
5. Place the foam bottom-side up and find and mark the center point of the bottom-side of the foam. Mark out a 7.62 cm by 7.62 cm (3 in by 3 in) square centered on this center point. Lightly but evenly coat the foam within this marked out square with a cryanoacrylate adhesive.

6. Position the foam back in place on top of the enclosure base using the index marks to duplicate the previous position. **Immediately wipe up any excess glue that oozes out.** Place 7.62 cm by 7.62 cm (3 in by 3 in) square of 6 mm (1/4 in) plywood centered on top of the foam. Use a wood clamp to compress and hold the foam in

position. Before applying the clamp make sure the wood square is not positioned over the cable glands where it would cause flexure damage to the cables when compression is applied. **Immediately wipe up any excess glue that oozes out.** Allow the glue to set for about 15 minutes before removing the clamp.

Diagram not to scale

Enclosure Foam Padding



Constructing the Collar Electronics Package

Mounting the Collar and Satellite Modem PCBs

1. Use sidecutters to clip off the pointed ends of the plastic pins extending from the mounting holes in all four corners of the satellite modem. Use a punch of the same diameter as the plastic pins to push the pins out of the mounting holes. Remove the nut and lock washer from the SMA jack connector on the modem. Separate and remove the two pieces of the metal case and gasket surrounding the modem printed circuit board (PCB). **Do not remove the metal shielding box attached to the PCB.**

2. Cut a rectangular piece, 0.64 cm by 5.08 cm (¼ in by 2 in), from a 0.24 cm (3/32 in) thick sheet of ABS plastic. Scribe diagonal lines from each corner of this rectangle to mark its center point. Drill a 3/16 hole at the center point mark. This rectangular piece of ABS will, hereafter, be referred to as the "PCB mount".

3. Hold the modem PCB with the side bearing the metal shielding box facing downwards. Locate the 26-pin header on the PCB. On the end of the PCB with the 26-

pin header, slide the PCB mount under the PCB and into the overhang formed by the PCB and the metal shielding box. Center the PCB mount relative to the width of the modem (note, both are 5.08 cm [2 in] wide). Using a marking awl, mark the center point of each of the 2, relevant modem mounting holes onto the PCB mount. Drill a 3.18 cm (1/8 in) hole at each center point mark on the PCB mount. The center points of these holes should be 4.3 cm (1.69 in) apart. Use a file to round over a corner of the PCB mount. Move along the long axis of the PCB mount and round over the corner opposite of the first corner.

4. Use a #1 Phillips screwdriver to screw a 2.54 cm (1 in) long, #4-40, stainless steel machine screw completely into one of the holes near the ends of the PCB mount. The head of the screw should now be seated against the mounting board. Thread on a #4 stainless steel nut onto the machine screw and tighten the nut against the PCB mount using a nutdriver. Repeat with another screw in the other mounting hole.

5. With the screws in the PCB mount pointing upwards, slide a #4 nylon washer over each screw. Find the galvanized mounting screw that was packaged with the enclosure and insert that screw through the center hole in the PCB mount. This screw should now be pointing downwards. Using a #2 Phillips screwdriver, attach the PCB mount to the enclosure base by screwing the galvanized screw into the boss in the bottom of the enclosure base interior. Use the boss in the end opposite where the cables enter the enclosure base. The rounded corners of the mounting board should face toward the nearest enclosure end-wall.

6. Completely insert ends of the two #4 machine screws on the PCB mount through the mounting holes on the modem PCB. The connector-side of the modem PCB should be facing up. Thread on a 0.95 cm (3/8 in) long, #4 nylon spacer over each machine screw. Insert the machine screws through the mounting holes of the collar PCB and connect this PCB with the modem PCB via the mating 26-contact connectors on both PCBs. Slide a #4 nylon washer on each machine screw. Thread on and gently tighten a #4 stainless steel nut on each machine screw. You now have formed a sandwich of the two PCBs and this sandwich is mounted to the enclosure base.

7. Route the GPS antenna cable alongside the sandwich then gradually bend it back 180 degrees and plug it into the GPS jack on the collar PCB.

8. Thread the modem antenna cable connector onto the antenna jack on the modem. The cable should now form a loop which points straight up out of the enclosure base.

Constructing the Battery Pack

The collar power supply consists of a battery pack of either one or two pairs of D cells ($LiMnO_2$) where, the two cells of each pair are wired in series. Packs containing only two cells are designed to minimize collar weight and bulk. Four-cell packs are used where collar weight and bulk is less of a concern than deployment length. In four-cell packs, the two pairs of D cells are wired in parallel to roughly double the capacity of the

pack. **Safety glasses should always be worn when constructing collars. They are particularly important when working with lithium batteries which can catch fire or explode if shorted.**

1. The lithium-metal D-cells used in the battery pack come supplied with solder tabs at each terminal. To construct the 4-cell battery pack used in the cattle collar, you will need to solder the tabs of two cells together to form cell pairs (please refer to diagram below). Begin by putting on your safety glasses if you do not already have them on. Identify the polarity marks on the first two cells. Position both cells so the positive (+) marks and tabs are on top. Rotate the cell at your left hand so its tabs point directly towards you. Rotate the cell at your right hand so it tabs point towards you and then rotate the cell 45 degrees further to the left towards the left-hand cell. Now slide the cell together so the tabs of the cells overlap. **Be absolutely certain that the positive tabs of both cells are on top, otherwise, mixing the polarity when the cell tabs are overlapped will cause a dangerous short.** Secure the positioning of the cells by tightly wrapping a rubber band around them. If necessary, adjust the rotation of the right-hand cell so that the end of its tab overlaps the tab of the left-hand cell at about that tap's center-point. This position leaves the distal half of the tab on the left-hand cell available to receive wiring. Repeat this procedure for the second pair of cells.

2. Remove the rubber bands on each cell-pair and wrap each pair with 2 wraps of electrical tape to further secure the two cells together. Use a multimeter to check the voltage for each cell-pair. Nominal voltage for a cell-pair made with new, fresh cells is about 3.2 volts. If the measured voltage is less than 3 volts, the cell-pair has been partially depleted, possibly from accidental shorting, and should not be used for field deployments.

3. From rolls of black and red, 22 gauge, stranded hook-up wire, cut four wires (two red and two black) each 13.34 cm (5 ¼ in) long. Strip about 6 mm (1/4 in) of the insulation from both ends of each wire. Apply a light layer of solder to each wire end using a soldering iron. Refer to the diagram below and solder the appropriate wire to the appropriate tab. Prior to soldering the second end of each wire, slide two pieces of 4.8 mm (3/16 in) dia. heat shrink 1.91 cm (¾ in) long onto the wire and slide them out of the way and away from the heat of soldering. Once the soldering of a wire is complete, slide the heat shrink over each soldered tab to insulate the tab and to provide strain relief at the solder joints. Note that one of the cell-pairs will have two wires, a red and a black, soldered onto the same tab. Before soldering this tab, it is helpful to twist these wires together, solder the wire ends together, and then slide a piece of heat shrink over both wires. Allow the wires to cool before attempting to slide the heat shrink on, otherwise, the heat from the wires may cause the heat shrink to shrink prematurely.

4. Identify the red wire labeled "6 volt supply" in the diagram. Find this same red wire in your battery pack. Use a multimeter to confirm this voltage is being supplied. Solder and crimp a male contact onto the end of this wire. Select a male locking connector housing and find the arrowhead-shaped impression on the housing. Insert the male contact into the rear end of the housing through the hole marked by the impression.

Push the contact forward into the hole until the tang on the contact snaps up into the second square hole in the housing. The contact should now be engaged and will not come back out if the wire is lightly tugged upon.

5. Identify the red wire labeled “3 volt supply” and the black wire labeled “Ground for 3 volt supply” in the diagram. Find these same wires in your battery pack. Use a multimeter to confirm this voltage being supplied. Solder and crimp a female contact to each of these wires. Select a female locking connector housing and find the arrowhead impression above one of the holes in the rear end of the housing. Insert the contact attached to the red wire into this hole and press the contact forward until its tang engages in the second square hole in the top of the connector housing. Repeat this process for the contact on the black wire in the remaining hole in the rear end of the housing.

6. Apply short lengths of electrical tape over all the battery terminals or their respective tabs to insulate them from possible shorting. Lay one of the cell pairs down flat on its widest dimension. Hold the remaining cell-pair vertical and butt this pair against the end of the horizontal pair. Wrap some electrical tape around both pairs to hold them is this configuration. The battery pack should now have taken on an “L” shape with the 3 volt and 6 volt supply leads extending out of the interior angle of the “L”. Fold up any excess wire used to connect the two cell-pairs together and tuck it into the crease between the cells of nearest cell-pair. Wrap some electrical tape around these cell-pairs to further secure the cells together and to keep the excess wiring safely tucked away.

7. Apply a piece of label tape across the horizontal leg of the “L” shaped battery pack. Use a multimeter to make a final check of the voltages. Write these voltages and the date of construction on the label tape.

Installing the Battery Pack

1. Invert the enclosure lid and position the battery pack on the bottom-interior of the lid. The lid is designed so that it fits on the base in only one orientation so, you need to make sure the pack is located in the proper end of the lid. The vertical leg portion of the “L” shaped pack should be located in the end of the lid that corresponds with the end of the enclosure base where the antenna cables enter. The horizontal leg of the pack should extend towards the bottom center of the enclosure lid. Take note of this positioning and then remove the pack from the lid.

2. Invert the battery pack and apply a thick even coat of RTV-167 silicone adhesive on the bottom side of the horizontal leg of the pack. Reposition the pack inside the enclosure lid as described above. Firmly press the pack downward to form a good adhesive bond with the bottom of the enclosure lid.

3. Apply a bead of silicone along the juncture between the long sides of the lid and the horizontal leg of the pack. Double check for correct positioning and orientation of the pack inside the lid. Allow the silicone adhesive to dry for at least 12 hours.

4. When attaching the exclosure lid to the base, the vertical leg of the pack will extend down into the base, pressing down slightly on the satellite modem PCB. During deployment, we recommend placing a rectangle of 6 mm (1/4 in) foam on top of the modem to prevent compression or impact damage to the modem from the battery pack. Note that the loop in the modem antenna cable should fit into the void between the pack and the end-wall of the enclosure lid. The GPS antenna cable should be routed alongside the modem PCB and should not be located in a place where the battery pack can damage the cable. A cable tie can be useful to anchor the GPS cable out of harm's way.

Recognize this battery pack is designed specifically to accommodate the components listed in the cattle collar BOM. The shape and placement of your battery pack may require some experimentation to fit your particular application.