PROCEDURES: Detailed parts lists and assembly instructions for the COTS GPS devices, device firmware, description of the GPS data format, and collar construction are available at https://github.com/jkarl/COTS_GPS_Collars.

GPS Location Tracker Construction: The core of our COTS GPS collars is an inexpensive and readily available Arduino microcontroller (Figure 1, center of top-left panel). The Arduino handles the initiation and polling of the GPS unit and writing of the location information to a data card. To maximize battery life and control timing of GPS readings, we used a low-power timer board. The timer board passes current from the battery to the Arduino until the Arduino signals that it has completed recording GPS information. At that point, the timer board cuts off power to the Arduino and enters a sleep cycle. The duration of the sleep cycle was set to 5-minutes. The COTS GPS collars were powered by a single-cell 3.7v lithium polymer battery. Given measurements of power consumption from prototype units, we estimated that a 3,500 mAh battery would last approximately 30 days.

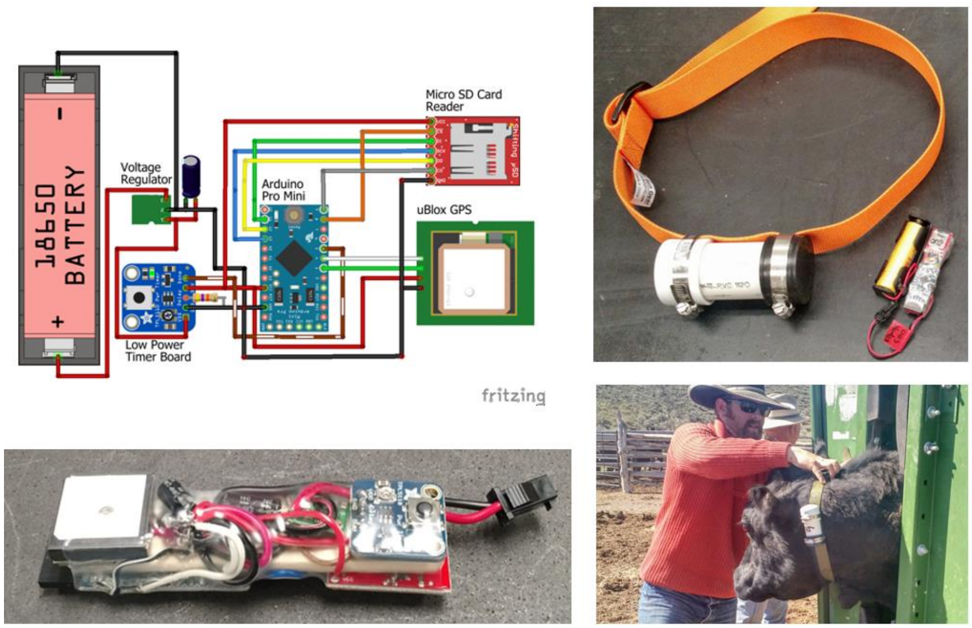

Figure 1. GPS Collars made from commercial off-the-shelf (COTS) parts (left, top and bottom). GPS collars were contained in PVC housing secured to a 1.5" width nylon belt (top right). Twenty-five COTS collars and 24 existing collars were deployed on a herd of 100 cows for 6 weeks in a southern Idaho study area (bottom right).

Collar Construction: The collar assembly for the COTS GPS units was made from 38mm (1.5") nylon webbing belts (1.37m [54"] long) with aluminum "ladderloc"-style buckles and 102mm (4") of 38mm (1.5") diameter polyvinyl chloride (PVC) tubing (Table 1). A fixed PVC cap was glued to one end of the tubing, and a removable neoprene rubber cap was fit over the other end. The PVC housing was secured to the nylon belt using 63.5mm (2.5") hose clamps (Figure 1).

GPS Collar Testing: Twenty-five COTS GPS collars were assembled and each run for 24 hours to verify proper functioning. To evaluate accuracy and precision, we placed a COTS GPS collar at a location with known coordinates and measured the displacement between the COTS GPS collar locations and the known point. To test the durability and field performance of the GPS collars, we deployed the 25 COTS GPS collars along with 24 existing GPS collars from Dr. Jim Sprinkle in a study area southwest of Malta, Idaho, USA. Both collar types were set to record at 5-minute intervals. From a herd of 100 cows with calves, 49 cows were selected at random and fitted with either a COTS or Knight GPS collar. Cattle were released into a 65-ha (141-ac) holding pasture for 5 days before being turned out to a larger pasture for approximately 6 weeks.

ACCOMPLISHMENTS or RESULTS: Total cost including per COTS GPS collar was $54.78. This included $3.45 per collar in parts shipping charges (6.3% of total cost). Cost savings could have been realized by sourcing components from different suppliers or prioritizing free shipping. However, due to project timing constraints (6 weeks between when funding became available and when collars needed to be installed on cattle for the field trial), quick availability was prioritized over shipping cost. Actual costs will fluctuate over time with supplier costs and parts availability. Subsequent redesign of the collars (see below) should drop the per-unit cost down below $45 each. Accuracy of the COTS GPS collars was equivalent to the existing collars. At 1-second intervals, average displacement from the test location for the COTS collars was ~4m. At 5-minute intervals, average displacement was ~ 20m.

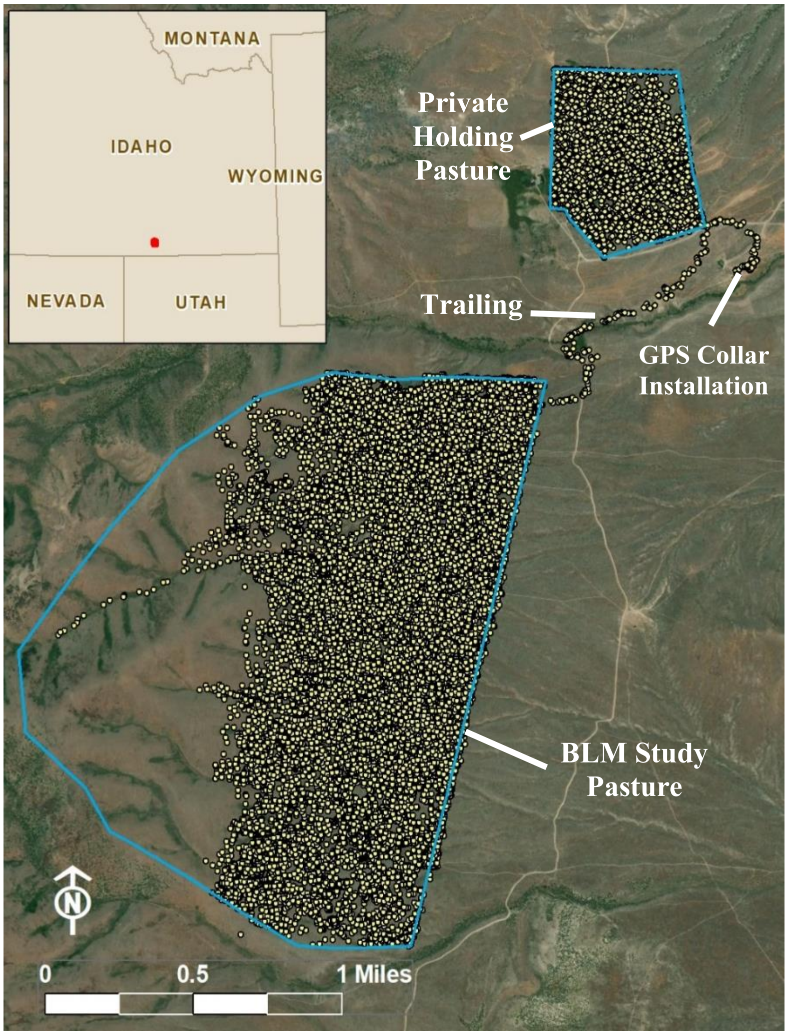

Figure 2. Livestock locations from the trial of COTS GPS collars and existing GPS colars. Study site was one of the grazing pastures for the UI Sage Grouse and Spring Grazing Study.

None of the COTS GPS collars were lost during the study, but two of the existing GPS collars were lost. At the conclusion of the study, no evidence of excessive rubbing or chafing of the COTS collars on the cows was observed. Through the trial study, a total of ~ 87,000 livestock locations were recorded (Figure 2). Notable observations from these GPS locations were: 1) livestock use was well distributed in the study area, and 2) movement patterns of individual animals did not show strong evidence of clustering or herding within the study area.

Longevity of the COTS GPS collars was mixed. During the holding pasture test, 1 of the COTS collars experienced failure of the GPS device and recorded no data. While all the remaining collars lasted through the holding pasture trial, no collars operated the full 30-day design requirement. Average lifespan of the COTS GPS device was 18 days. Several factors contributed to this shortened lifespan. In several devices, inconsistent grounding caused by faulty soldering or wiring caused inconsistent performance. In five devices, packaging of the GPS device in the collar led to an exposed reset button becoming depressed when the collar was jostled (e.g., when the cows walked). This had the effect of interrupting GPS fixes, causing loss of data and shortening the interval between GPS readings causing the battery to deplete faster.

While not perfect, we considered the outcomes of this first trial to be a limited success. Using information from the trial, we were able to redesign the COTS GPS collars to minimize or eliminate many of the problems encountered during the first year. One significant change for 2019 is the use of a custom-printed circuit board to reduce wire/solder connections that were a point of weakness (Figure 3). In the redesign we were also able to eliminate the timer board and several other components and shift the power management to the microcontroller. This simplifies the system, reduces cost, and allows for more sophisticated GPS management. For 2019, we plan to deploy GPS collars at four new study sites (50 collars at each site; 200 collars total). Production of GPS units for 2019 has begun.

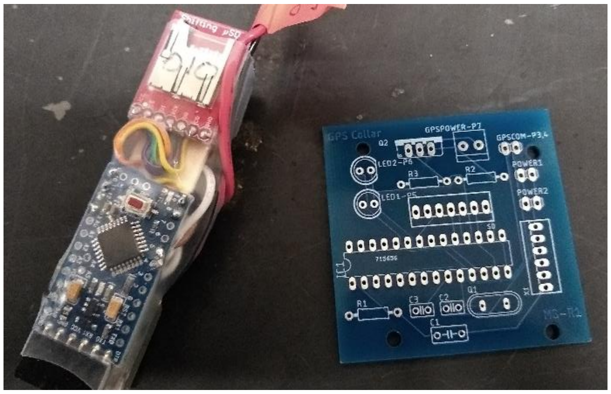

Figure 3. Custom circuit board for redesigned GPS collars (right) compared to 2018 COTS GPS Collar (left). Custom circuit board will remove most of the wire connections and exposed reset button that were a point of weakness in the original design.

PUBLICATIONS or OUTPUTS: The results of this study have been described in a manuscript in preparation to submit to Rangeland Ecology & Management (Karl, J.W. and J.E. Sprinkle. *In prep.* A livestock GPS collar from commercial off-the-shelf parts: technical note. Rangeland Ecology & Management). Additionally, the GPS collar design and preliminary results were key to receiving a NRCS Conservation Innovation Grant for $661,000 for using livestock GPS collars to tie field measures of utilization to satellite models of seasonal biomass change. This new NRCS funding will assist in addressing Objectives 2 and 3 of this project. The NRCS-CIG grant, in particular the livestock GPS collars, were featured in a UI Press release and appeared in several regional newspapers and radio shows.

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