QUARTER 1 2005

ANIMAL VEHICLE CRASH MITIGATION USING ADVANCED TECHNOLOGY

SPR 3(076) & Misc. Contract & Agreement No. 17,363

for

Oregon Department of Transportation
Research Unit
200 Hawthorne SE, Suite B-240
Salem OR 97310

and

Federal Highway Administration
400 Seventh Street SW
Washington, DC 20590

and

Alaska Department of Transportation and Public Facilities, and the Departments of Transportation of California, Indiana, Iowa, Kansas, Maryland, Montana, Nevada, New Hampshire, New York, North Dakota, Pennsylvania, Wisconsin, and Wyoming

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Monthly report Animal-vehicle pooled fund study

January 2005

Task 1: Identify potential advanced technology systems 100%
This task is complete

Task 2: Locate potential study sites 100%
Task complete

Task 3: Document existing site conditions 100%
No progress on this task

Task 4: Implement and test systems 80%

General

1. WTI-MSU has contributed another $30,000 to ensure that the MT site (Yellowstone) can be investigated with regard to system reliability and system effectiveness between 1 January and 30 June 2005. This reflects WTI-MSU's dedication to the project and delivering the best possible product to the 15 DOT's and FHWA.

2. The following articles on the project appeared in the media in January 2005:

2 January 2005	The Missoulian	Sensor would alert drivers to wildlife near road
2 January 2005	The Times-News	Sensor would alert drivers to wildlife near road
2 January 2005	The Billings Gazette	Park tests road-kill technology
4 January 2005	Spitting Image	Wildlife Sensors
3 January 2005	ESPN Outdoors	Yellowstone to test road-kill technology
January 2005	Montana Greenpower	Solar-Powered Elk Early Warning System Installed on Yellowstone Highway

MT site (Yellowstone)

1. The animal detection part of the system has been functional between the following dates:
   Since 22 Nov 2004 through 14 January, perhaps it never went down.

Clarification: the lights started to flash at a suspiciously high frequency on Sat 15 January. The animal detection part may have continued to operate, but we don't know until the memory chip has been analyzed by STS. STS is analyzing the memory card this week (first week of February 2005).

2. The driver warning part of the system has been functional between the following dates: Since Mon 13 Dec 2004 through 14 January 2005.
   Clarification: the lights started to flash at a suspiciously high frequency on Sat 15 January. On Tue 18 January 2005 the beacons were unplugged and the signs were removed. Many thanks to MDT for doing this.

3. The problem may be related to the lack of a straight line of sight between some of the radio stations and the master station. If there is a problem with the reception it may result in long error messages. If the error message is longer than a certain maximum the system crashes and is unable to turn the beacons off.

4. STS had been developing new software to address this problem as well as a couple of other issues (memory buffer and overwriting problem). STS had been testing the new software for about a week with good results by the time the problem was reported and was able to send the new software within a couple of days.

5. WTI-MSU visited the site on 26 and 27 January to upload the new software, swap the memory card and re-initialize the animal detection part of the system. These actions were successful; all detection zones were active again. The detection part of the system was active again on Wed 26 January 2005 and is believed to be still active today (2 February 2005). Once the memory chip has been investigated by STS, once we know what may have happened on 15 January, and once we know that that problem has been fixed we will ask MDT to plug the beacons back in and attach the warning signs.

6. WTI-MSU hired a graduate student (Whisper Maillet) to collect snow tracking data to investigate the reliability of the system. Whisper started Fri 28 January 2005. Once the system is confirmed to be working reliably and once the driver warning part of the system has been re-activated, and once the drivers have been exposed to the warning signs for some time Whisper will also start collecting vehicle speed data.

7. The first snow tracking data are encouraging (see task 6).

PA site

1. No further news.

Task 5: Collect post-implementation site data 12%
No progress on this task during the reporting period.

Task 6: Evaluate system effectiveness, acceptance and performance 2%
Data on system reliability and system effectiveness will be collected over the coming months. A start was made by analyzing data patterns between 22 Nov and 3 Dec. WTI-MSU started snow tracking on 26 January 2005 to investigate the reliability of the system. The results for the first night were encouraging: about 10 elk crossed detection zones E and 4 and were indeed detected by the system. Elk have been found to cross in the road section with the system almost every night.

Task 7: Produce final report 0%
A draft report was presented to the TAC before the TAC meeting (15-16 Dec). Comments are welcome.

Additional Work / Issues
The actual co-ordination between all the organizations and people involved for the MT (Yellowstone) site as well as the Pennsylvania site continues to be much more labor intensive than anticipated.

Marcel Huijser

Monthly report Animal-vehicle pooled fund study

February 2005

Task 1: Identify potential advanced technology systems 100%
This task is complete

Task 2: Locate potential study sites 100%
Task complete

Task 3: Document existing site conditions 100%
Task complete

Task 4: Implement and test systems 80%

General

1. As discussed in December 2004 we are to have another TAC meeting around mid May 2005. Please indicate 3 consecutive days that you would be able to participate in a TAC meeting in Bozeman (see Attachment A).

MT site (Yellowstone)

1. Attachment B contains a report that investigates the reliability of the animal detection system along. We have investigated the reliability of the system since 26 January 2005 to evaluate whether the warning signs should be re-attached and the beacons should be re-connected.

A. System reliability

2. There is no indication of system failure between 26 January 2005 and 5 March 2005. The system seemed to be stable. However, a large number of false positives began to occur on 5 March 2005 in detection zone 1 (see *B. Beacons and warning signals*).

3. We conducted more detailed data analyses for two periods: 26 January 2005 - 31 January 2005 and 25 February 2005 – 5 March 2005 to investigate the reliability of the animal detection system. Interpretation of the detection data saved by the system suggests that at least 55% of all detections were related to animals approaching or crossing the road. This percentage should be regarded as a minimum estimate as some, perhaps many, of the “unclear” detections (28%) may also have related to animals that approached or crossed the road. The “unclear” category is also likely to have included isolated detections caused by vehicles driving close to the edge of the pavement.

4. The total time that the flashing warning lights would have been activated is about 2:24 h per day maximum (based on a median of 48 detections per day and the assumption that consecutive detections are at least 3 minutes apart). The actual time that the warning lights are activated is likely to be much lower, because consecutive detections are usually strongly clustered (much less than 3 minutes apart).

5. The distribution of animal crossings over the day, as detected by the system, and the direction of travel match local knowledge of the behavior of the elk. The elk usually spend the day on the forested slopes. In the evening the elk travel down the slopes and cross the road to feed on the grasses and willows in the valley bottom. In the morning they leave the valley bottom, cross the road and travel up the forested slopes. The patterns in the detection data confirm that the system detects elk and confirm a correct interpretation of the detection data.

6. We conducted daily snow tracking sessions in certain periods. For this report we analyzed snow tracking data for two periods: 26 January 2005 - 31 January 2005 and 25 February 2005 - 28 February 2005. Within these periods we documented 53 elk, 14 coyote and 1 wolf crossings. We compared the snow tracking data to the detection data saved by the system. Both the detection and snow tracking data indicate that most animal crossings, especially elk, occur at the north end of the road section covered by the animal detection system. The similarity in distribution suggests that the system is indeed detecting large animals, especially elk.

7. More detailed analyses indicate that the system detected a minimum of 72% of all elk crossings recorded through snow tracking. Assuming that the crossings detected by the system are indeed caused by animals, 80% of these detected crossings were confirmed through snow tracking. These percentages may not seem high or high enough, but there are errors associated with both interpretation of detection data and with snow tracking. In addition, there are known blind spots in the system, especially in detection zone 8 (see later). As a result of these factors, the abovementioned percentages are minimum values. These data indicate that the system is indeed detecting elk that approach and cross the road.

8. The system detected a human model passing through the detection zones at 20 m intervals in most locations. However, there is a substantial blind spot in detection zone 8 and to a lesser extent in detection zones B, 0, D, 5, 2 and 9. The blind spots in detection zones 8, B, 3, and D are the result of curves and slopes that make the beam shoot over the head of the model in some areas. The blind spots in detection zone 5 and 9 may be related to radio failures rather than true blind spots. The blind spots in detection zones 0 and 2 require additional investigation as the terrain seems relatively level and straight. Nevertheless, the

test indicates that the system should be able to detect elk passing through the detection zones in most locations.

9. A software update on 10 February 2005 resulted in a substantial reduction of the radio failure rates. However, some stations lack a “line-of-sight” with the master station and still have relatively high radio failure rates. While these radio failures do not result in overall system failure they could result in some false negatives; i.e. an animal approaches and crosses the road but is not detected. Detection zone 5 and 9 seem most affected. However, tests with a human model showed that detection zone 5 detected the model 7 out of 8 passages. Detection zone 9 detected the model 5 out of 6 passages.

10. The analyses indicate that the system was stable between 26 January 2005 and 5 March 2005 and that the system indeed detected large animals that approached and crossed the road. However, blind spots and radio failures for some stations may have resulted in some false negatives. On the other hand, the system seems to detect elk well on the most heavily crossed road sections at the north end of the road section covered by the system. However, one may never assume that an animal detection system can detect all animals that approach or cross the road at all locations under all circumstances.

B. Beacons and warning signals

11. The system started to produce false positives on 5 March 2005 in detection zone 1 about 25 minutes after WTI-MSU personnel had left the site. The data since 5 March 2005 are not part of this report, but preliminary analyses indicate that the false positives seem to last several hours at a time. STS and WTI-MSU are currently investigating the cause for these false positives. The sensors of detection zone 1 may no longer be fully aligned, but it is also possible that water (from snowmelt) that has collected in the ditch causes deflections of the microwave signals

12. Despite the reliability of the system until 5 March 2005, WTI-MSU advises not to connect the beacons and not attach the warning signs for the moment, mostly because of the abundance of false positives in detection zone 1 since 5 March 2005. However, STS could deactivate detection zone 1 and eliminate the abundant false positives should the connection of the beacons and attachment of the warning signals be desired on short term. This would result in a system that is mostly functional but that has a “blind spot” in detection zone 1.

13. The false positives in detection zone 1 followed after the animal detection system appeared to work reliable for more than 5 weeks (see later). This demonstrates that the performance of the animal detection system can change, perhaps because of damage to the equipment, perhaps because of environmental factors such as the presence of water in a ditch. Whatever the

cause for the present problem may be, it seems that frequent access to and interpretation of the detection data, perhaps at least once every 24 hours, may be required before the beacons are connected and the warning signs are attached. A modem would allow for remote access to the data but STS has experienced delays with obtaining specialized parts. Nevertheless, STS expects to have the modem ready for installation within a couple of days.

14. WTI-MSU believes that the detection system demonstrated an effective ability to detect large animal passages during the evaluation period. However, to assure that system remains effective on an ongoing basis. WTI-MSU advises to connect the beacons and attach the warning signs once:

- The cause for the false detections in detection zone 1 has been identified;
- Measures have been taken to prevent these false detections from happening again;
- Remote access to the system has been established.

However, one may also decide to connect the beacons and attach the warning signs once:

- Detection zone 1 has been deactivated.

C. Other

15. WTI-MSU stopped snow tracking on 4 March 2005 because of a lack of snow. However, we resumed snow tracking on 24 March 2005. We will continue to gather as much information on system reliability as we can.

16. The beacons and warning signs have not been up since 18 January 2005. This means that WTI-MSU has not been able to evaluate the effect of activated warning signals on vehicle speed, nor on a potential reduction in animal-vehicle collisions. However, we have collected valuable information on system reliability (see attachment B) and additional base line data on vehicle speed to add to our measurements from 2002.

PA site

1. Nick Henningsen from Oh Deer removed Oh Deer's equipment from the site on 31 January 2005. However, he did not remove the antennas. The antennas are not a problem at this time but Penndot will remove the antennas after a couple of months.

2. Oh Deer has not been in touch after their contract was terminated.

Task 5: Collect post-implementation site data 30%

See attachment B, report on system reliability.

Task 6: Evaluate system effectiveness, acceptance and performance 2%
Data on system reliability and system effectiveness will be collected over the coming months if the warning signs are attached.

Task 7: Produce final report 70%
A draft report was presented to the TAC before the TAC meeting (15-16 Dec).
This draft report will be updated with new data (e.g. attachment B) and the comments that were provided by the TAC members before the upcoming TAC meeting in May 2005. Additional comments are welcome.

Additional Work / Issues
The actual co-ordination between all the organizations and people involved for the MT (Yellowstone) site as well as the Pennsylvania site continues to be much more labor intensive than anticipated.

Marcel Huijser

Attachment A

Please fill out whether you will be able to attend the upcoming TAC meeting in May and the days that you are available**. Please return this info by e-mail to Marcel Huijser at WTI-MSU ASAP:** mhuijser@coe.montana.edu

Name	Representing	Attending (yes/no)	Want field visit? (yes/no)	Dates available between 1 May and 31 May (at least 3 consecutive days)
Clint Adler	AK			
Pete Hansra	CA			
AJ Nedzesky	FHWA			
Jaime Reyes	IA			
Sedat Gulen	IN			
Alisa Babler, Rex McCommon or Dave Church	KS			
William Branch	MD			
Deb Wambach	MT			
Kevin Bruski	MT			
Allan Covlin	ND			
Greg Placy	NH			
Jay Van Sickle	NV			
Kyle Williams	NY			
Felix Martinez	OR			
Jon Fleming	PA			
Keith Knapp, John Kinar or Richard Stark	WI			
Bill Gribble or Kevin Powell	WY			
Pat McGowen	WTI-MSU			
Marcel Huijser	WTI-MSU			
Amanda Hardy	WTI-MSU			
Christie Hendrix	Yellowstone NP			
Wayne Brewster	Yellowstone NP			
Terry Wilson	STS			
Lloyd Salsman	STS			
Partly attend				
Steve Albert	director WTI-MSU			
John Taylor	deputy director WTI-MSU			
Not attending because of abandonment of PA site				
Pat Wright	WTI-MSU	PA		
Rhonda Stankavich	PA	PA		

Notes:

1. The meeting will be in Bozeman, MT.

2. Travel and stay will be covered by the project for representatives whose line is white (not yellow).

3. Please let me know if you would like to see anything done/organized differently from the previous TAC meeting in December 2004.

Attachment B

Status of the animal detection system along Hwy 191 in Yellowstone National Park

Marcel Huijser[1] and Lloyd Salsman[2]

[1] WTI-MSU. Detection data and snow tracking data analyses and report.
[2] STS. Radio failure analyses and report.

Snow tracking data collected by: Whisper Camel, Amanda Hardy and Marcel Huijser

24 March 2005

1. Introduction

The animal detection system started to detect large animals reliably on 22 November 2004 (Table 1). On 13 December 2004 the warning signs were attached and beacons were connected. However, the animal detection system was found to still have two problems:

1. The software caused the detection data to overwrite code for radio messages after 15 days. This caused faulty radio reports and the detection data were no longer transmitted to the master station. If the beacons were flashing at that moment, the beacons were not shut off. This happened on 31 December 2004, but the system seemed to have recovered by itself on 9 January 2005. However, the software may have been damaged and the system may not have detected animals reliably, perhaps the date of 9 January 2005 was wrong as well. The detection system stopped recording information completely on 10 January 2005, but this date may not be correct either.
2. The number of unsuccessful radio contacts was still relatively high, mostly due to curves and slopes that prevent a straight line of sight to the master station. These failed radio contacts did not result in system failure but it did result in the failure to report potential detections to the master station.

The first problem led to the removal of the warning signs and the disconnection of the beacons on 18 January 2005. The software was upgraded twice (26 January 2005 and 10 February 2005) to correct the overwriting of the code 15 days after system initialization and to allow for more radio communication time to reduce the number of failed radio contacts. The detection part of the system has been functional again since 26 January 2005, but the driver warning part has not been re-activated yet (Table 1). This report investigates the reliability of the system since the software changes were made.

Table 1. Status of the animal detection and driver warning part of the animal detection system.

Period	Animal detection part	Driver warning part
22 Nov ’04 - 13 Dec ‘04	Functional	Not connected
13 Dec ’04 - 31 Dec ‘04	Functional	Connected
31 Dec ’04 - 18 Jan ‘05	Not functional	Connected
18 Jan ’05 - 26 Jan ‘05	Not functional	Not connected
26 Jan ’05 – 5 Mar ‘05	Functional	Not connected
5 March ’05 - present	Functional, except for false positives in detection zone 1	Not connected

2. Methods

2.1. Detection data

The detection data from 26 January 2005 until 11 March 2005 were extracted from the data file (see appendix A). The raw data (over 4 MB) or an excel spreadsheet with the condensed data are available on request. WTI-MSU interpreted the data patterns for two periods: 26 January 2005 - 31 January 2005 and 25 February 2005 – 5 March 2005. We distinguished seven categories (Table 2). The detections caused by researchers were excluded from all analyses. Each "day" started and ended with the arrival of the researchers at the site (usually in the morning hours) or, if the researchers did not visit that day, a "day" started and ended at noon.

Table 2. Detection data categories.

Category	Definition
Animal crossings	All detections that showed "something" crossed the road and triggered the system in detection zones on opposite sides of the road. We included detections that seemed to be related to the crossing (immediately before and after).
Traffic/snowplow	A series of consecutive detections in adjacent sections with the direction of travel. The detections may be caused by snow spray from snow plows, signal reflections from large vehicles (buses/trailers) or vehicles driving close to the edge of the road.
Traffic Black Butte Ranch	All detections in detection zone 3 between 7:00-23:00 that had no match on the other side of the road.
Trailhead	All detections in detection zone 7 between 7:00-19:00 and that had no match on the other side of the road.
Error	Detections associated with a failed radio report or detections that occur simultaneously in adjacent sections.
Researchers	Detections caused by the presence of researchers during site visits, including snow tracking.
Unclear	Detections that do not fall in any of the above categories and that cannot be readily explained based on the data patterns alone.

The interpretation of the data based on the detection patterns is subject to errors. This is particularly true for the category "unclear". Although detections may seem random and do not seem to fit any particular pattern, they may very well be related to real world events. For example, an animal wandering in the right-of-way may trigger the system but the animal may not cross the road and may not trigger the system on the other side. The animal may also cross the road much farther up or down the road, thus producing seemingly unrelated detections. In

addition, the beam with the microwave signals is not at a constant height above the ground. Rises or low areas, slopes and curves result in areas where the beam may shoot over an animal's body or where it is very low to the ground (e.g. 18 inches). Thus relatively small mammals such as coyotes but also elk may be detected in some areas and not in others, resulting in seemingly isolated and unrelated detections. Furthermore, traffic can also cause isolated detections, especially in detection zones 8, 9 and 1 where the beam is relatively close to the edge of the pavement. Vehicles that drive on the edge of the pavement may only be detected in one or two detection zones. These detections may not fit any particular pattern and may be classified as "unclear".

Other interpretation problems occur when several animals cross the beam at the same time; i.e. within 2 seconds of each other. These crossings will be recorded as one beam break event rather than several. Thus the number of "animal crossings" detected by the system typically underestimates the actual number of animals that crossed the road. This is especially true for gregarious species such as elk. This underestimation does not affect the functioning of the system, but it is one of the factors that complicate system reliability investigations.

2.2. Snow tracking data

WTI-MSU conducted snow tracking sessions on both sides of the road for the full 1 mile road length covered by the animal detection system. The dates of the snow tracking visits are listed in table 2. The visits were mostly conducted in the morning hours. On the first day of each session we did not record any tracks, we only erased all present tracks in the snow with a rake. On the following days for each session we recorded and erased all new tracks of large animals that crossed in between the transmitters and receivers of the animal detection system since the last visit. When an animal appeared to have crossed the road we specifically looked for a matching track on the other side of the road. The tracking data for 26 January 2005 – 31 January 2005 and 25 February 2005 – 28 February 2005 were compared to the detection data saved by the animal detection system.

Table 2. Snow tracking visits.

Snow tracking sessions	Comments
26 Jan '05 - 14 Feb '05	26 Jan '05 – 31 Jan '05 analyzed for this report, 1 Feb '05 – 14 Feb '05 not analyzed yet
18 Feb '05 - 21 Feb '05	Not analyzed yet
25 Feb '05 - 28 Feb '05	Analyzed for this report
4 Mar '05 - 6 Mar '05	No tracking due to insufficient snow

Snow tracking data are not without error either. Tracks can be simply overlooked, tracks may have been filled in by blowing snow or new snow, or they may have fainted due to melting. In addition, there was a hard icy crust on the snow on most days, and some animals may not have

left tracks. In addition, the number of animals traveling in a group and animals that step in each others tracks may be miscounted or improperly estimated. Finally, the snow coverage was poor and relatively far from the road and the detection zones on some snow tracking days, increasing the probability of missing tracks.

2.3 Blind spots

We tested for potential false positives by using a human as a model for elk. We passed through the detection zones at 20 m intervals (Table 3). We recorded the location and time of each passage and compared these notes with the detections recorded by the system. We walked well passed the detection zone and allowed for a minimum of three minute interval between consecutive passages to avoid desensitization of the beam. Locations on which the system failed to pick up the model were identified as "blind spots".

Table 3 Test dates for the different detection zones.

Detection zone	Test date
E, 4, B, 7 and C	5 February 2005
D, 6, A, 2, 5 and 9	7 February 2005
8, 1, 0 and 3	13 February 2005

2.4. Radio failures

The animal detection system uses a radio-based, polled telemetry system to monitor the beam break activity throughout the array. Beacon control commands are communicated to the beacon-equipped stations by the radio link. As the master station polls each receiver and the beacon at station 3 (see Appendix B), the format of the reply is checked. An invalid message format is considered a radio failure. A time limit is imposed on each polling interrogation. If the polled station does not reply within a specified time, a radio failure is declared. Radio failures can result in missing beam break reports and "false negatives"; i.e. a large animal that approaches or crosses the road is not detected. Therefore the radio failure rate should be as low as possible.

The MTC software incorporates the facility to log critical data about individual radio link conditions. The radio telemetry data includes: radio data (format) failures, radio protocol failures, and received signal levels for each link. Analysis of the radio log data by STS indicated deficiencies in the radio link operation. Two software modifications were made by STS to improve the performance of the radio link system. WTI-MSU personnel installed the updates on 26 January 2005 and 10 February 2005. STS analyzed the radio link conditions to evaluate whether the software updates resulted in reduced radio failure rates.

3. Results

3.1. Detection data

The number of detections per day does not show a consistent increase or decrease in the periods investigated (Figure 1). However, the number of detections was relatively high early March 2005. The total number of detections per day varied between 18 and 110, with a median of 48 detections per day (Figure 1). The flashing warning lights are programmed to flash for 3 minutes after the last detection. If we assume that there is at least 3 minutes interval between consecutive detections the flashing warning lights would be activated for 144 minutes (2:24 h) on a day with 48 detections. However, most detections are highly clustered and have much shorter time intervals between them, resulting in a drastic reduction of the total flashing time per day.

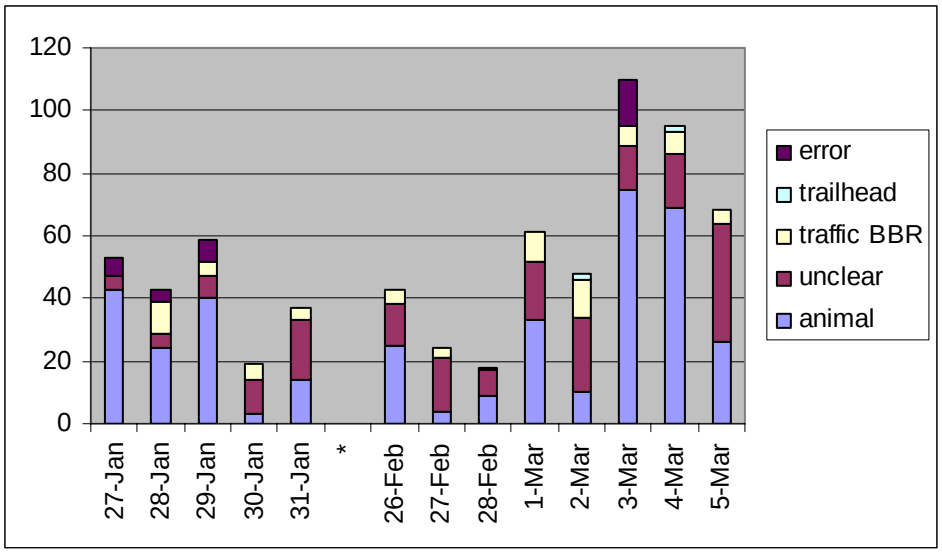

Figure 1. The number of detections per day between 27 January 2005 and 31 January 2005 and between 26 February 2005 and 5 March 2005.

About 55% of all detections were classified as crossings, 29% was classified as unclear, and 10% was classified as traffic on the Black Butte Ranch access road (Figure 2). There were no detections that were clearly related to snow plows or traffic during the periods investigated. The detection data that were classified as crossings were split into west and eastward movements, based on which side of the road detected the movement first and

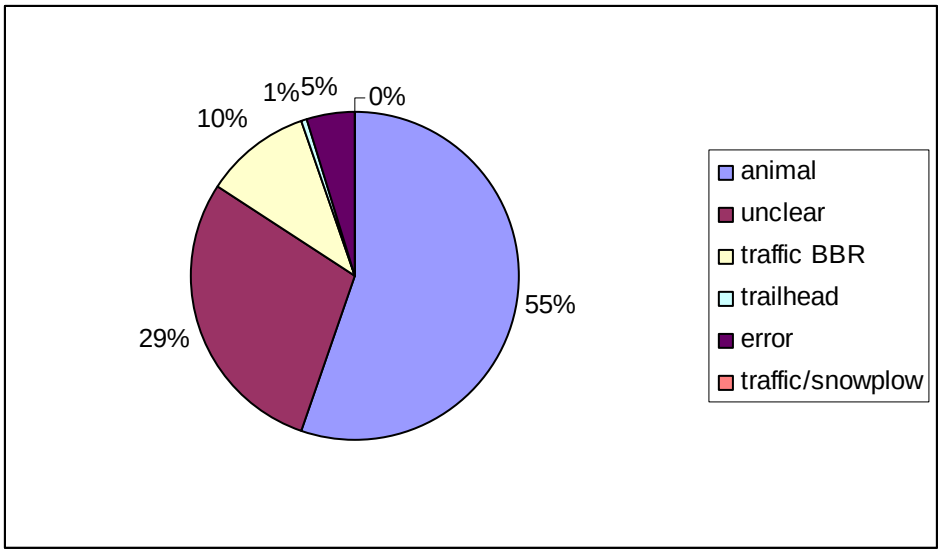

Figure 2. The percentage of detections per category (total = 678) between 27 January 2005 and 31 January 2005 and between 26 February 2005 and 5 March 2005.

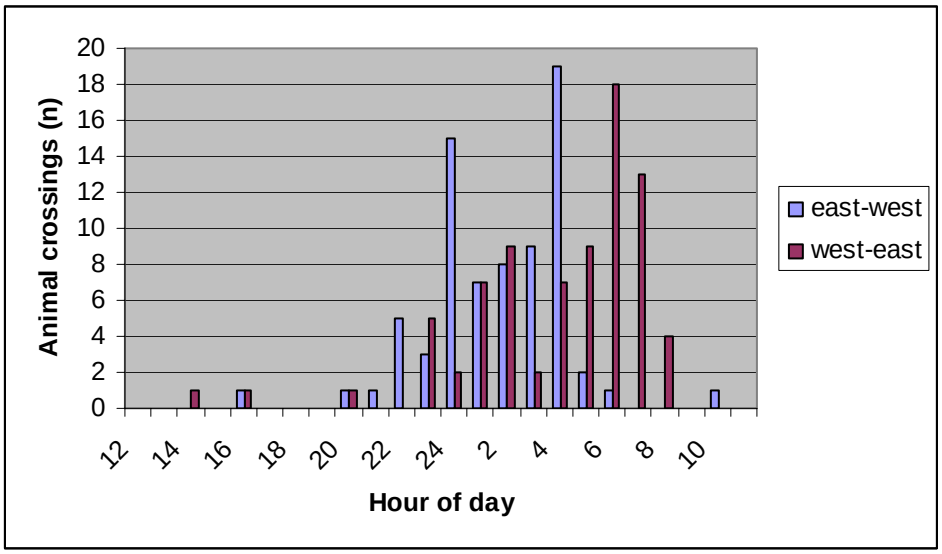

Figure 3. The number of crossings per hour of day for west and eastward movements between 27 January 2005 and 31 January 2005 and between 26 February 2005 and 5 March 2005.

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last. Then the detection data were grouped per hour. Most of the westward movements occurred between 22:00 and 5:00 with a peak at 24:00 (midnight) and 4:00 (Figure 3). Most of the eastward movements occurred between 1:00 and 8:00 with a peak between 6:00 and 8:00.

A quick scan of all the detection data showed no indication of “down time” for the animal detection part of the system between 26 January 2005 and 5 March 2005, indicating that the software problem that occurred 15 days after initialization of the system has indeed been solved through the software updates on 26 January 2005 and 10 February 2005.

3.2. Snow tracking data

Within the investigated period we encountered the tracks of three mammal species (Table 4).

Table 4. Species identified through snow tracking between 27 January 2005 and 31 January 2005 and between 26 February 2005 and 28 February 2005.

Species	Crossings or presence in right-of-way (n)
Elk (*Cervus elaphus*)	53
Coyote (*Canis latrans*)	14
Wolf (*Canis lupus*)	1

3.3. Comparison detection and snow tracking data

For an overall comparison between the detection data and the snow tracking data we plotted the crossings for each detection zone combination for both the snow tracking data (Figure 4) and the detection data (Figure 5). The pattern of crossing frequencies for the different detection zone combinations is similar for the detection and snow tracking data. Most crossings occurred between detection zones E and 4 on the north end of the road section covered by the system. The snow tracking data confirmed that it is mostly elk that crossed the road there. Coyotes crossed mostly in the middle of the road section covered by the system.

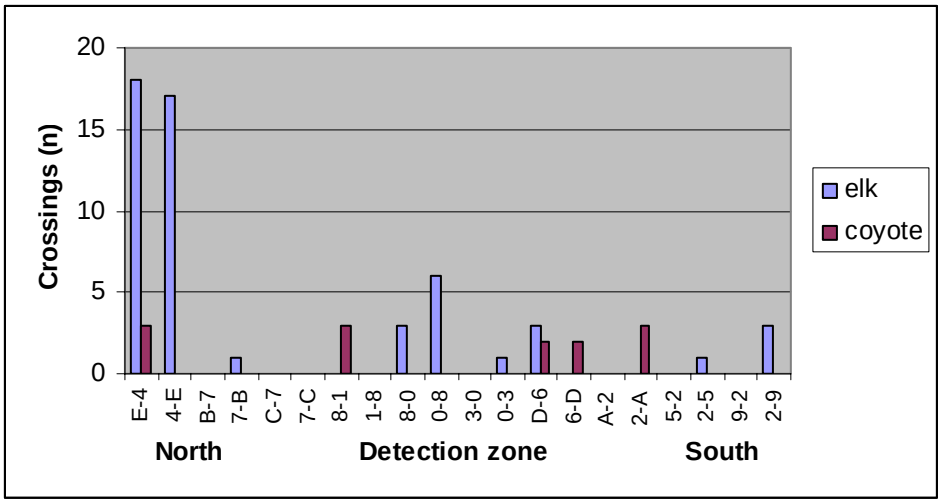

Figure 4. The number of recorded crossings for elk and coyote through snow tracking between 27 January 2005 and 31 January 2005 and between 26 February 2005 and 28 February 2005. See appendix B for the exact location of the detection zones.

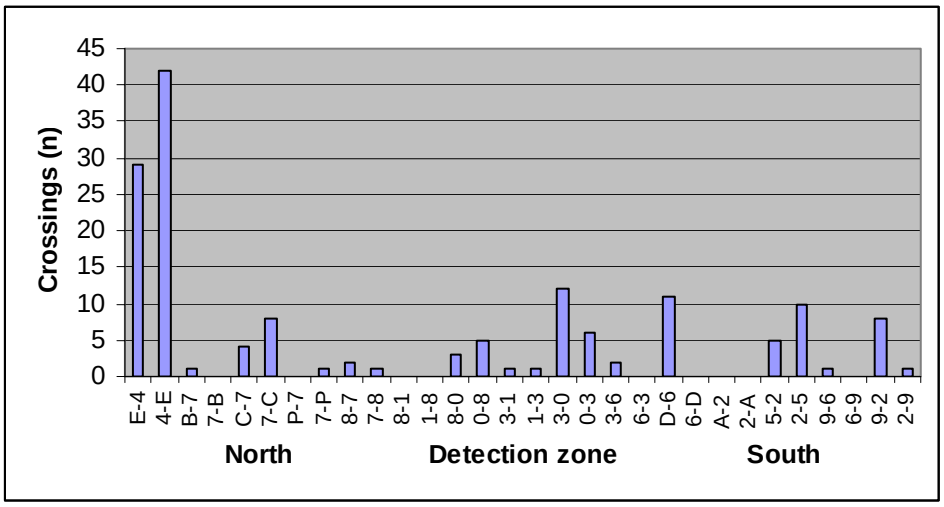

Figure 4. The number of crossings based on interpretation of the detection data between 27 January 2005 and 31 January 2005 and between 26 February 2005 and 5 March 2005. See appendix B for the exact location of the detection zones.

A day by day and detection zone by detection zone comparison showed that 72% of all elk recorded crossings and 14% of all recorded coyote crossings were detected by the system (Table 5). On the other hand 80% of all crossing detections by the system were confirmed through snow tracking (Table 6).

Table 5. The number of recorded crossings for elk and coyote through snow tracking between 27 January 2005 and 31 January 2005 and between 26 February 2005 and 28 February 2005 and the number and percentage of these crossings detected by the animal detection system.

Species	Snow track crossings (n)	Detected (n)	Detected (%)
Elk	53	38	71.7
Coyote	14	2	14.3

Table 6. The number of crossings detected by the animal detection system between 27 January 2005 and 31 January 2005 and between 26 February 2005 and 28 February 2005 and the number and percentage of these crossings confirmed through snow tracking.

Species	Detection crossings (n)	Tracked (n)	Tracked (%)
unknown	152	122	80.2

3.4. Blind spots

The animal detection system detected the human model on most locations in most detection zones (Figure 5 and 6). However, there is a very substantial blind spot in detection zone 8, and to a lesser extent in detection zones B, 0 D, 5, 2 and 9.

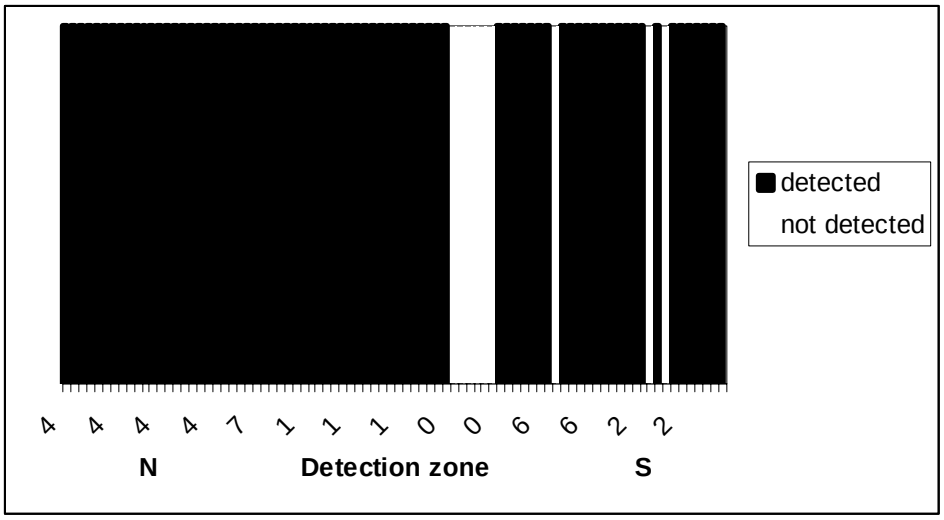

Figure 5. Blind spots of the detection zones on the east side of the road.

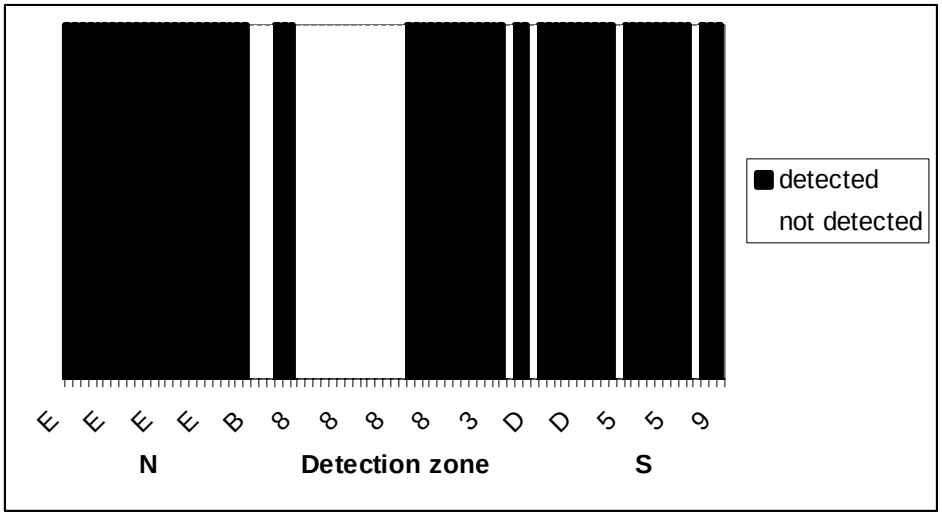

Figure 6. Blind spots of the detection zones on the west side of the road.

3.5. Radio failures

After the software modification on 26 January 2005, the “15 day” malfunction was corrected; the system has remained operational between 26 January 2005 and 5 March 2005. However, the radio failures for some of the links were still relatively high after the first software update on 26 January 2005 (Figure 7). Stations 3, 7, and 21 showed particularly large errors (Figure 7; use right-hand vertical scale for these values). Station 21 is located immediately opposite the master station and has a Yagi antenna with a gain of 8.2 dBi. This arrangement results in a signal overload at the master station. The AGC (automatic gain control) cannot respond to the high signal levels quickly enough before the message timeout occurs (resulting in a radio failure).

This fault was partially corrected in the second software modification on 10 February 2005 (Figure 8).

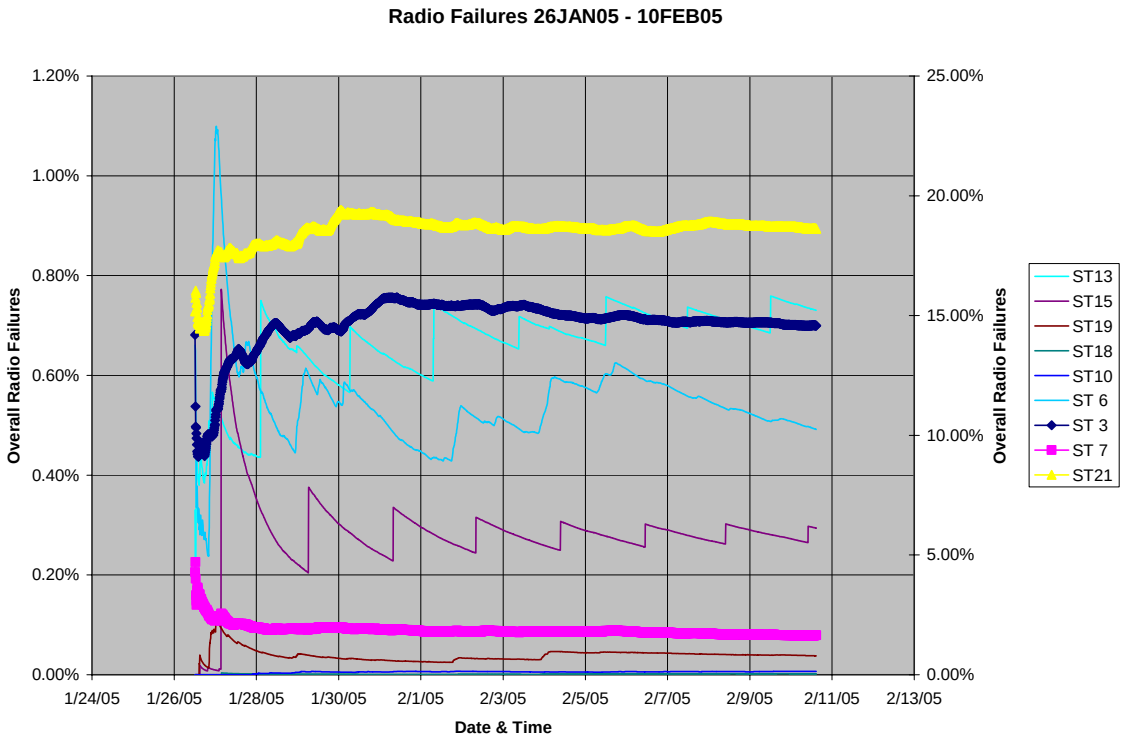

Figure 7. Radio failures prior to the first software update on 26 January 2005.

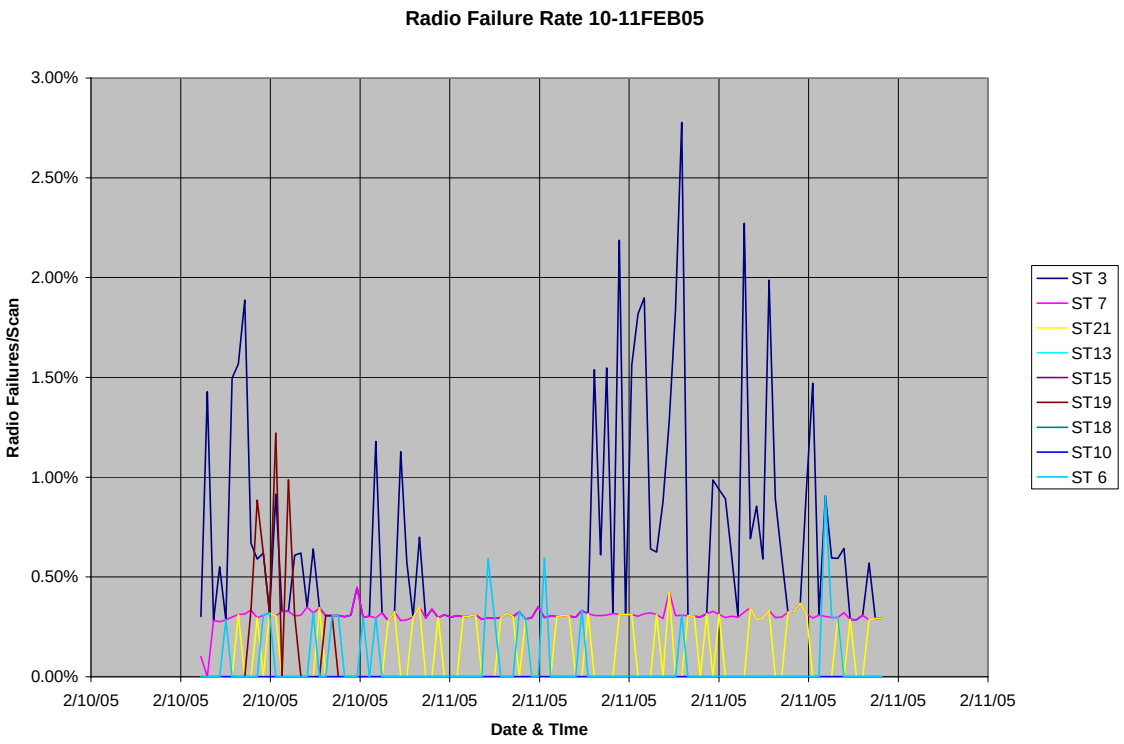

Figure 8. Radio failures after the second software update on 10 February 2005.

The second software modification on 10 February 2005 allowed more time for the radio to recover from a failed contact. The total scan time for the array remained well under two seconds (i.e., a beam break anywhere in the array will be reported within two seconds). This scan time preserves the response time of the animal detection system. An order of magnitude improvement in radio performance (for the poor performing links) was achieved after the last update (Figure 8).

A more detailed plot of the signal strengths for each link is shown in Figure 9. This plot shows the signal level margins above the minimum sensitivity of the receiver (-110 dBm). Station 21 shows the worst signal strength performance. Station 19 shows a decreasing path loss after midnight. This phenomenon is coincident with snowplow operation at that same time (as logged by the system). It appears that it snowed at the site before and shortly after midnight. Then the snow stopped and the signal strength gradually increased again. The data from station 19 show that adequate signal strength is available to operate the system even during precipitation events.

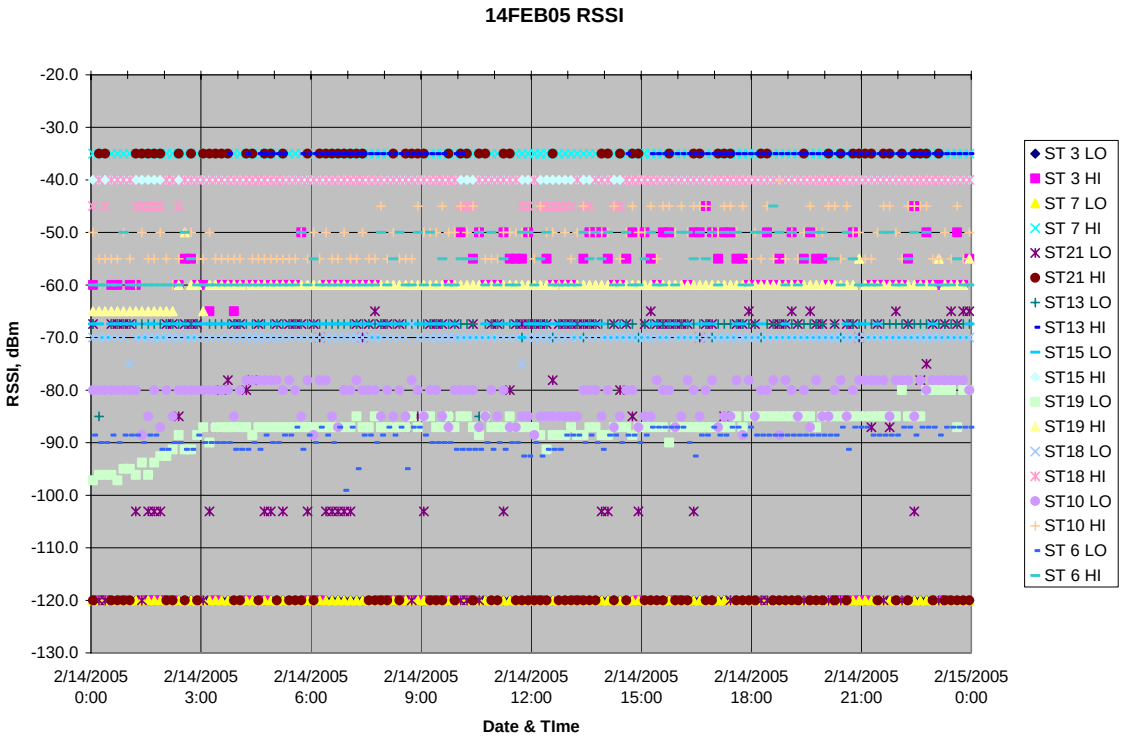

Figure 9. Received signal strength on 14 and 15 February 2005.

On 17 March 2005 WTI-MSU personnel placed the Yagi antenna of station 21 slightly out of alignment (about 5 degrees) to further reduce signal overload at the master station. However, the effect of this change has not been evaluated yet.

4. Discussion

The patterns in the detection data indicate that most of the detections, at least 55%, seem to be related to animals crossing the road. However, it is likely that some of the detections currently classified as “unclear” are actually related to animal movements as well. Therefore the 55% value should be seen as a minimum estimate. The percentage of suspicious detections, potential system generated errors, is currently estimated at 5%. This is mostly due to failed radio reports from station 3 (detection zone 5 and 9). This station seems to suffer from a lack of a straight line of sight with the master station and signal reflection from a rocky slope (see later). However, within the investigated periods there is no indication of a high number of highly suspicious detections or false detections generated by the system. The system seems to have been detecting animals between 26 January 2005 and 5 March 2005 without system failures, e.g. failure 15 days after system initialization. The system seemed to be stable during this period.

The distribution of detected animal crossings over the day and the direction of travel match the observations from the caretakers of the Black Butte Ranch (Greg and Sara Knetge). The elk

usually spend the day on the forested slopes. In the evening the elk travel down the slopes and cross the road to feed on the grasses and willows in the valley bottom. In the morning they leave the valley bottom, cross the road and travel up the forested slopes. This seems to confirm the ability of the system to detect elk and a correct interpretation of the detection data.

The pattern of the number of detected crossings for each detection zone combination matches the number of recorded crossings through snow tracking. Detection zone E and 4 are by far the most heavily used zones by elk when they cross the road. Again, this seems to confirm the ability of the system to detect elk and a correct interpretation of the detection data.

The system detected a minimum of 72% of all elk crossings recorded through snow tracking. Assuming that the crossings detected by the system are indeed caused by animals, 80% of these detected crossings were confirmed through snow tracking. These percentages may not seem high, but there are errors associated with both interpretation of detection data and with snow tracking. In addition, there are known blind spots in the system, especially in detection zone 8. These factors make that the abovementioned percentages are minimum values, and that at least some of the detections that are currently marked as “unclear” are also related to animals approaching and crossing the road. Nevertheless, the current data indicate that the system is indeed able to detect elk that approach and cross the road. However, one may never assume that an animal detection system detects all animals that approach or cross the road under all circumstances.

The system detected a human model passing through the detection zones on most locations. However, there is a substantial blind spot in detection zone 8 and to a lesser extent in detection zones B, 0, D, 5, 2 and 9. The blind spots in detection zones 8, B, 3, and D are the result of curves and slopes that make the beam shoot over the head of the model in some areas. The blind spots in detection zone 5 and 9 may be related to radio failures rather than true blind spots. The blind spots in detection zones 0 and 2 require additional investigation as the terrain seems relatively level and straight. Nevertheless, the test indicates that the system should be able to detect elk passing through the detection zones on most locations.

The second software update on 10 February 2005 resulted in a substantial reduction of the radio failure rates. However, station 3, and to a lesser extend station 6 (beacon) still have relatively high radio failure rates. This is related to the lack of a “line-of-sight” with the master station. This error could be corrected by a protocol change in the use of the radio system. However, this requires a hardware modification. Despite the radio failures for station 3 the system still detected a human model in detection zone 5 (station 3) 7 out of 8 passages. Detection zone 9 (station 3) detected the model 5 out of 6 passages.

Station 21 showed the worst signal strength performance. The anomalous activity may be the result of signal overload and/or AGC failure for this link. Pushing the antenna slightly out of alignment may have helped, but the effect has not been evaluated yet.

Conclusion and recommendations

The patterns in the data suggest that most of the detections can be related to real world events. There is no evidence for an extremely high number of false positives between 26 January 2005 and 5 March 2005. The total time that the flashing warning lights would be activated is about 2:24 h per day maximum (based on a median of 48 detections per day and the assumption that consecutive detections are at least 3 minutes apart). The actual time that the warning lights are activated is likely to be much lower though as consecutive detections are usually strongly clustered (far less than 3 minutes apart).

STS and WTI-MSU suggest thinking about:

1. A software change could be made to deactivate detection zone 3 that shoots across the Black Butte Ranch access road during the day. This may reduce the number of detections by about 10%. However, animals that cross the road in that section during the day will then no longer be detected. While this option reduces “false positives” it increases “false negatives” which one may want to avoid at all times. Normal operation (animal detection) would be resumed overnight.

In addition, STS and WTI-MSU suggest:

2. STS thinks they can improve the performance of station 3 (detection zone 5 and 9) by changing the antenna alignment. However, this requires additional research. The performance of other stations may be improved as well.

WTI-MSU has more snow tracking data available for analyses which will be included in the final report. Snow tracking was no longer possible starting 4 March 2005. If more snow falls and is present Fridays through Mondays, WTI-MSU will resume snow tracking.

Appendix A

Key to the raw detection data from the animal detection system along US Hwy 191 in Yellowstone National Park since 22 November 2004

The lines that begin with a '5' in the raw data file relate to events in one of the beams. Select these lines and delete the other lines when interpreting the data.

The selected lines have data in the columns:

A. Date
B. Time (M7 stands for Mountain time in relation to GMT)

The following columns relate to events to the beam of the respective detection zones. The first symbol identifies the beam (see the figure for location of the detection zones). The second symbol is either a "0" or a "1" and related to the status of that detection zone; "0" = no break, "1" = break. All changes in the status of the beam are reported; i.e. a break of the beam in one of the detection zones results in a line with a "1" behind the detection zone identifier, and the end of the break of the beam in that detection zone results in another line with a "0" behind the detection zone identifier. Some stations are hard to reach with the radio because of slopes and curves. For example, the radio of station 9 does not always come in. This also results in an event, but these events are marked with an "R" indicating radio failure.

C. Detection zone 9
D. Detection zone 5
E. Detection zone A (or 10)
F. Detection zone D (or 13)
G. Detection zone 3
H. Detection zone 8
I. Detection zone C (or 12)
J. Empty column because there is only one receiver at station 13
K. Empty column because there is only one receiver at station 15
L. Detection zone B (or 11)
M. Detection zone E (or 14)
N. Empty column because there is only one receiver at station 19
O. Detection zone 4
P. Detection zone 7
Q. Detection zone 6
R. Detection zone 2
S. Empty column because of the radio for the beacon at station 6
T. Empty column because of the radio for the beacon at station 4 (master station)
U. Detection zone 0
V. Detection zone 1
W. Beacon code

Appendix B

Location and layout of the animal detection system along Hwy 191 between mile marker 28 and 29 in Yellowstone National Park

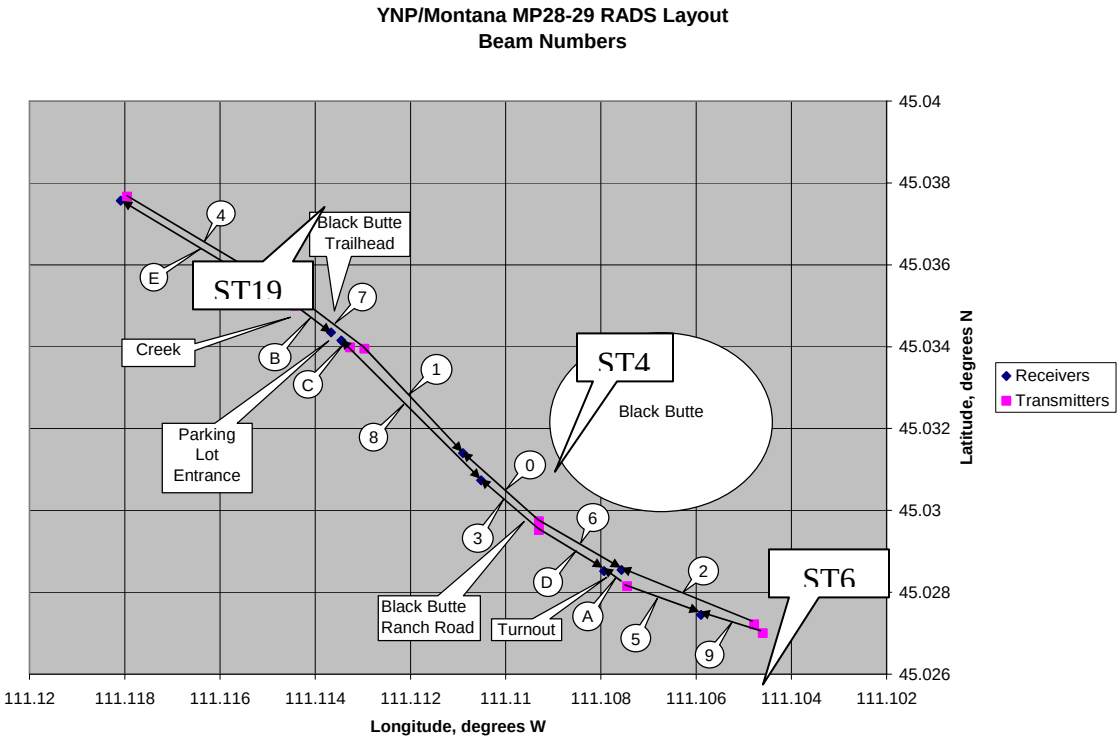

Figure 1. Layout of the system with coding of the detection zones.

Figure 1 shows a scaled layout for the RADS indicating significant features, including detection zone codes. The Black Butte Trailhead, Black Butte Ranch Road, and the creek feeding the Gallatin River are also marked. The parking lot is located on the west side of the road immediately south of the trailhead. A traffic turnout is located just south of the BB ranch access road on the west side of the highway.

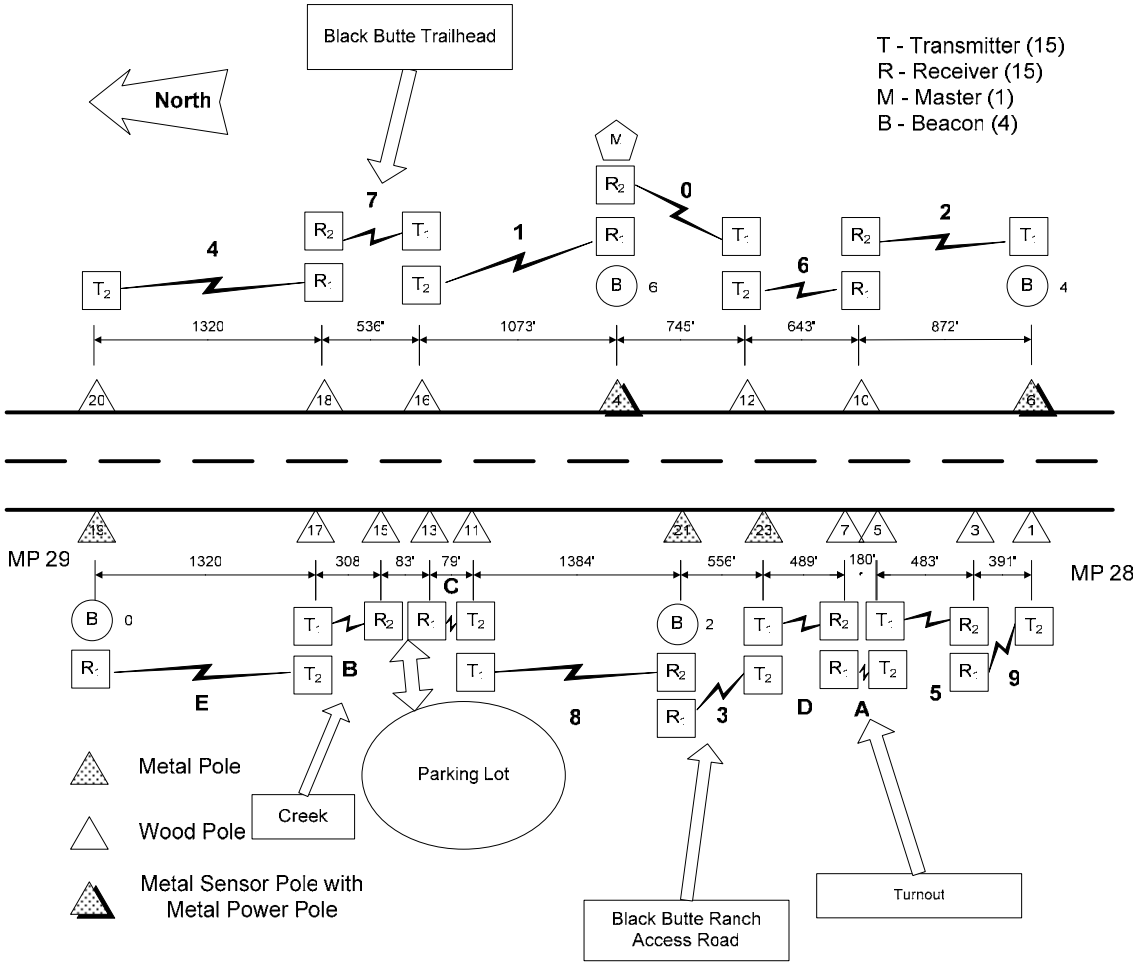

Figure 2 Layout of the system.

Figure 2 shows the equipment complement and designations for the system, including station numbers (in triangles).

Monthly report Animal-vehicle pooled fund study

March 2005

Task 1: Identify potential advanced technology systems 100%
This task is complete

Task 2: Locate potential study sites 100%
Task complete

Task 3: Document existing site conditions 100%
Task complete

Task 4: Implement and test systems 80%

General

2. I asked advice from WTI-MSU legal representatives whether it would be considered “good practice” to no longer reserve the money for Oh Deer Inc. whose contract was terminated. They stated that since Oh Deer removed the equipment and since they have not contested the termination of the contract (terminated on 11 January 2005) we can indeed spend the money that had been reserved for Oh Deer.
3. Alisa Babler (KS DOT) asked us for any publicly available publications on animal detection systems before January 26, 1997. Apparently this would make Oh Deer’s patent invalid.

MT site (Yellowstone)

a. Whisper Camel and Marcel Huijser went down to the study site several times to investigate what might be causing the bursts of false positives in detection zone 1. These investigations included signal strength readings and using a scope to see if the sensors were still aligned, as well as investigating the presence of potential objects or reflections in the path of detection zone 1 (melt water in ditch, rocks, trees, shrubs)
b. A contact of STS from Big Sky checked the alignment of the sensors in detection zone 1 (16 March 2005) and looked for anything in the way of the beam. There was no clear cause for the false positives in detection zone 1.
c. Further data analyses showed that detection zone 9 sometimes shows suspicious detections, perhaps false positives. Again, field surveys did not show a clear cause.

PA site

3. Oh Deer has not been in touch after their contract was terminated.

Task 5: Collect post-implementation site data 30%

Task 6: Evaluate system effectiveness, acceptance and performance 2%

Task 7: Produce final report 70%

Additional Work / Issues
The actual co-ordination between all the organizations and people involved for the MT (Yellowstone) site as well as the Pennsylvania site continues to be much more labor intensive than anticipated.

Marcel Huijser