XII. ON-BOARD SYSTEMS: ATRC RESEARCH ACTIVITY

PROJECT DATA COLLECTION

As described in Chapter X, the collection of research data for the on-board system evaluation in Year Five presented new challenges for the ATRC. There was no longer a third-party evaluation support consultant, since NAU had completed their workscope in the previous winter. With the seven test snowplows dispersed across northern Arizona, all of the field activity would take place in the truck cabs during the long season of patrolling and plowing the highways. These two accessory warning systems had no performance recording features, and the snowplow operators were responsible for observing, interpreting and reporting of operational activity and storm condition information.

The ATRC staff developed a variety of data collection methods and resources for the 2002-03 winter that were intended to not be too burdensome, requiring minimal extra effort from the real evaluation team, the 14 primary snowplow operators.

Operators' Shift Activity Reports

The most fundamental project reporting tool was ATRC's Shift Activity Report (Appendix E), which each driver was asked to complete after his 12-hour plowing shift was over. This form required mostly circles and check marks to record the conditions, with just a few key handwritten entries for date, name, Org, truck mileage and any warning-system concerns.

The overall response from the Orgs on ATRC's shift reports was quite poor, as they were the last piece of paperwork after all the other internal PECOS maintenance and vehicle logbook reports were filled out. Several Orgs submitted ATRC activity reports for up to 50 percent of the plow shifts recorded in the PECOS system, while one Org returned none. The return rate from the field was only 25 percent overall, but those reports provided valuable information on specific storm conditions that could be correlated to the storm data from the National Weather Service.

PECOS Maintenance Records

Fortunately, the proprietary PECOS data system, as the primary management tool for ADOT's entire winter maintenance program, was accessible to ATRC to document the full extent of the winter's snow-control activities. As discussed previously in Chapter X, this internal resource provided on-line verification of all shifts, full or partial, when any of the project snowplows were used on the roadway in winter maintenance activities. The various PECOS task codes include plowing snow, applying abrasives or deicers, winter storm patrol, storm debris and rock patrol, and spot ice control.

PECOS records also list manhours, equipment hours, materials quantities and distance traveled. Where gaps or overlaps were found in reviewing these records, the drivers' handwritten data entry sheets, which are also kept on file at the Orgs, were crosschecked for those specific dates. By searching the PECOS system records, ATRC staff were able to recover the key operational data that was needed to accurately document the utilization of all seven research snowplows for the Year Five winter.

PECOS records did not make ATRC's Shift Activity Reports redundant, as those forms included a variety of other significant observations on plowing activities, and on the roadway and weather conditions. The shift reports often captured driver comments, good or bad, which did not warrant filling out one of ATRC's Incident Reports. Driver comments frequently described how well or poorly the system was functioning in poor weather conditions including light and heavy fog, rain, and snow. Drivers also commented on having to stop to clean the camera lens or radar antenna. These comments were by far the most frequent, and one driver reported cleaning the night vision camera lens 18 times while plowing.

Driver Incident Reports

The second primary information resource that was provided to the project snowplow drivers was the ATRC Incident Report (Appendix F). These critical-event forms were requested initially by Bendix to collect real-word ADOT driver feedback, in order to refine their newly-introduced XVision system design and its marketing approach. Because of the relevance of the report for the ATRC's side-by-side evaluation of the two on-board warning systems, the form was also adapted for those plow drivers using the EVT-300 radar system.

The incident report form was provided to document any special situations where the on-board system did or did not perform as expected to help the driver respond to any roadway event. These reports were not limited to snowplowing, and especially in the case of the radar, feedback was requested for any unusual warning event in traffic. *The instructions to the drivers stated:*

"Incident" reports may be either positive or negative. They include:

- A warning of any object, stopped vehicle, person, or animal in the roadway.
- A warning you are rapidly overtaking a vehicle that you can't clearly see.
- Any observations of the road surface or other conditions affecting plowing.
- Any activity when you were able to plow more quickly, more precisely, or with fewer stops, due to visibility assistance information from the system.
- Any incident or situation when the system did not give accurate warnings.
- Any incident or situation when the system did not give any warnings.
- False warnings under specific weather or visibility conditions.
- Any other incident-specific safety or operational problems.
- Any other incident specific benefits to your safety and plowing efficiency.

Unfortunately, only a handful of these reports were submitted to ATRC during the relatively mild 2002-03 winter season. For the radar-equipped snowplows, only four "events" were reported on these forms. However, four other events were recorded on the shift activity reports. One of the four Orgs with CWS radar did not submit any reports – event or activity - over the entire winter.

Event reports on the night vision systems were slightly more complete, with ten events recorded. The operators' activity reports for XVision did not report any additional incidents. Comments on both systems as reported by the operators for events or incidents are summarized in Appendix F, together with similar comments that were sometimes recorded on the shift activity reports.

OPERATOR SURVEY RESULTS

The ATRC research plan called for periodic driver surveys through the winter, as the operators gained experience, and as the reliability of the two systems became more apparent with time.

This plan was successful despite the relatively mild winter season, and despite delays in the commissioning of several of the test snowplows.

As noted earlier, the three night vision systems were all operational by early December. The plow operators took the XVision survey three times, from pre-season to post-season, in December, February, and May. The potential time window of experience was shorter for the four EVT-300 CWS radar-equipped snowplows. In this case, only two surveys were conducted, first at mid-season and again in May, after the end of the winter.

The survey format utilized an opinion scale as to the basic plowing safety and efficiency factors of the warning systems, such as the driver's safety level, fatigue effects, and driving ability. The trends reported in the surveys reflect the overall level of satisfaction with each concept, and the level of confidence in the system as a benefit, rather than a burden, to the driver in a storm.

Both driver surveys were standardized to the greatest extent possible, but they did address the unique elements of each system. The final end-of-season surveys for both systems had an additional open-ended comments section, and the operators were asked for feedback on the potential for their warning systems to be deployed more widely in the future within ADOT. Driver responses to these surveys were generally complete and well expressed.

The complete summaries of the ATRC driver evaluation surveys are included as Appendix G for the radar system, and Appendix H for the night vision. A key aspect of these results, as noted above, is the comparison of comments and preferences from the beginning to the ending phase of the Year Five evaluation effort. In each Appendix, the rankings and the comments from the multiple iterations of the survey are listed together, to show how the drivers' opinions may have changed over the winter.

It should be observed that the very small pool of snowplow operators for each system allows for effective follow-up on individual comments, but it also allows extreme opinions at either end of the scale to stand out prominently. The ATRC, and the reader, must look within the summaries for the best overall sense of the operators' perspectives on each system being evaluated.

Collision Warning Radar Surveys (Appendix G)

For the radar system, most opinions (Part 1) did not change significantly over the winter; the initial impressions and driver expectations seemed to generally have stayed at about the same level through the season. There was some definite improvement shown as to effects on driver fatigue and distraction with the EVT-300 in use.

In Part 2 of the survey, the drivers commented on specific likes and dislikes about the system. As detailed in the Appendix, the forward warnings and the simplicity and reliability of the CWS system earned positive comments, but most drivers singled out the blind spot radar as the best feature. As to dislikes, false alarms at bridges and missed warnings were most significant for reducing confidence in the system. The display unit's mounting position was also criticized.

Open-ended questions made up Part 3 of the survey, and they dealt primarily with fatigue, range, warning preferences, and general advantages or disadvantages. Comments varied on the fatigue factors, but the system range and warning modes seemed to satisfy most of the drivers. A telling comment by one driver at season's end was that he "still had to use my own skills to do my job."

The post-season survey contained an added fourth section which asked the snowplow operators for their overall recommendations on the EVT-300 radar system. This is an area where many of the comments were well expressed and insightful; the drivers as a group put careful thought into their survey responses.

The first question in Part 4 of the final survey dealt with radar performance in a range of storm conditions. As shown in Appendix G, the operators generally indicated that the EVT-300 was effective in fog, rain, and light snow. As to heavy snow or whiteout conditions, most drivers responded that it worked well as long as snow did not build up heavily on the antenna.

The second question was especially crucial; it dealt with the usefulness of CWS radar for ADOT in any other non-plowing situations. The question was: "Is the system useful for you in any other operations apart from night plowing?" The drivers' responses were:

- Useful in daytime driving and warns when you are coming upon a slow-moving vehicle.
- No, snow plowing is the only operation that the system is useful (three "no" replies).
- It works just as well when driving in heavy traffic.
- Works great for the passenger-side blind spot.
- City driving during snow, it helps with cars pulling in front of you.

Other questions dealt with whether other drivers had driven the test plow over the winter and their reactions, and, more significantly, whether other plow routes in their Org would benefit from the CWS radar. As to any additional routes, the Orgs on I-40 replied in the affirmative – except for Flagstaff.

The final Eaton VORAD radar survey question was perhaps the most significant. The question was: "Based on your experience with this research project, should ADOT purchase more of these systems for those snowplow routes where impaired visibility is a frequent and serious problem?" The various drivers' responses are listed below:

- I think ADOT should put the systems in all snowplow trucks.
- ADOT should purchase additional systems where severe storms occur. The other additional places that might need this system are where there are high volume traffic areas.
- This product is very useful for over-the-road trucks. A plow truck has too many things in the way.
- The VORAD system would work better if used for summer driving.
- If it snowed more it would be useful but visibility (this season) has always been good.
- Yes, this system works without being too intrusive.
- Yes.
- No (two replies).

As can be seen from the various responses above, most of the ADOT plow operators found the EVT-300 to be a reliable and effective system overall, with four radar-equipped snowplows on the road for at least half of the 2002-03 winter season. The opinions expressed indicate a fairly high level of acceptance, tempered primarily by concerns over false and missed warnings. The project team's perspective is that further experience in winter storm conditions, along with consistent training and familiarization for the primary drivers, would further improve the driver satisfaction levels. It would also increase the overall acceptance of collision warning radar for both snowplowing and other fleet operations.

Infrared Night Vision Surveys (Appendix H)

The Bendix XVision snowplow operators also participated in satisfaction surveys during the 2002-03 winter. As all three systems were operational by early December, three surveys were conducted at two-month intervals with drivers of the night vision research plows, in December, February, and May. Only six primary snowplow drivers took the surveys. There were a certain number of gaps in the responses to the three surveys over the winter, which should be considered as a factor in any future planning based on the responses described below.

For the XVision survey, several opinions in Part 1 did change significantly over the winter. Because of ongoing problems with lens cleaning, the mid-winter ratings dipped lower in most cases, but at the end of the season, some ratings for the entire winter rose slightly. A question on whether driving ability was improved by XVision went progressively from "agree" to "disagree" and finally to "neutral" in May. Responses on image quality, fatigue, and distraction all went down by one level from mid-season on. A key question, whether XVision significantly improved safety on the road, fell two steps from "strongly agree" to "neutral" from mid-season on.

In Part 2 of the survey, the drivers commented on specific likes and dislikes about the system. As detailed in the Appendix, the season summary of "likes" was focused on better vision in most nighttime conditions. As to "dislikes," every negative comment was about the extent of loss of vision in snow and rain.

Responses to the open-ended questions in Part 3 of the survey were mixed. There was consensus among the drivers that fatigue was not an issue and that the design elements of range and display characteristics were completely satisfactory. The miscellaneous comments in Part 3 were almost all negative, dealing with the heating and cleaning issues of snow and moisture on the lens.

An additional fourth section of the year-end night vision survey asked the plow operators for their overall recommendations on the Bendix XVision system. This is an area where many of the comments showed frustration, as expected, but most of the drivers provided insightful responses.

The first question in Part 4 dealt with night vision performance in a range of storm conditions. As shown in the comment summary in Appendix H, there was a general driver consensus that the XVision system was effective in fog and light snow. However, it was less useful in rain, and the results were inconclusive in heavy or wet snow, due in part to the scarcity of severe snowstorms and whiteout conditions in the 2002-03 winter (perceptions of "heavy snow" also varied by site).

The second question was significant with regard to the potential uses of night vision systems for ADOT in any other non-plowing situations. Based on their occasional non-plowing use of the XVision system, thermal imaging seemed to offer improved vision to the drivers in more general conditions. In answer to the question: "Is the system useful for you in any other operations apart from night plowing?" the drivers' responses were:

- You are able to see more what's on the shoulder and road, which I think makes it more safe.
- No.
- Daytime too, could see roadway better and objects clearer.
- All day.

Other questions dealt with whether other drivers had driven the test plow over the winter and their reactions, and, more significantly, whether other plow routes in their Org would benefit from the night vision system. As to use on other highways, Kingman suggested two other plow routes, while Winslow suggested more tests on Interstate 40 before making a recommendation.

The final Bendix XVision survey question was perhaps the most significant. The question was "Based on your experience with this research project, should ADOT purchase more of these systems for those snowplow routes where impaired visibility is a frequent and serious problem?" The six plow operators' responses are listed below:

- No (two replies plus one blank).
- Yes I do!!!!!!
- Yes – useful in winter weather.
- Sure!

As can be seen from the various responses above, ADOT snowplow operators found the Bendix XVision system to be very effective in many conditions, based on testing with three plow trucks through the entire 2002-03 winter season. However, the technology was not effective in the winter storm conditions for which it was being evaluated. The XVision system's performance in heavy snow and rain was not just reduced, but in almost all cases reported, was eliminated.

This survey's results are no surprise, coming from frustrated drivers who had to stop 10 to 15 times in a shift to clean out the camera lens. The ATRC and the project's TAC recognize that while further experience in winter storm conditions is desired, solutions must be found to enable the XVision system to perform effectively in snow. Only by solving this problem can the Bendix system gain acceptance from ADOT for winter maintenance as well as other fleet operations.

Other Project Records – Weather Data

The ATRC had to make a considerable effort to develop background information for Year Five of the project, in particular to effectively reference the various snowplowing activity reports with the weather records for the winter. To assess the evaluation efforts, the severity of the winter, and the performance of the project snowplows, complete summaries of the season's storms were required. With the Bellemont National Weather Service station represented on the project TAC, it was relatively simple for ATRC to obtain storm records for 2002-03 from the NWS archives.

Table 8. NWS Weather Observation Stations for Project Plow Routes

Snowplow Evaluation Routes – Weather Records				
ADOT Maint Yard	**Route**	**NWS Weather Site**	**At Hwy Milepost**	**02-03 Snowfall**
Kingman	I-40	Diamond M Ranch	91	12.7*
Seligman	I-40	Seligman	121	6.4
Little Antelope	I-17	Flagstaff Pulliam Airport	337	54.9
Gray Mountain	US 89	Sunset Crater	430	27.5
Flagstaff	I-40	Walnut Canyon	204	35.4
Winslow	SR 87	Blue Ridge	300	39.0*
Chambers	I-40	Sanders Port of Entry	339	0.0
Source: National Weather Service (NWS) Records				** Incomplete Data*

There were some complications to this process. ATRC and NWS collaborated on defining the most appropriate weather observation station for each snowplow route. The selected routes and weather sites are listed in Table 8. All of northern Arizona except Kingman is in the Bellemont-NWS area of operations. For Kingman, the weather records had to be sourced from Las Vegas.

The National Weather Service provided ATRC with eight months of weather observations for the seven project test sites. The NWS records are generally kept by local observers, at hundreds of locations scattered across the state. A standard Form B-91, Record of River and Climatological Observations, provides a wealth of information in the hands of conscientious observers, although some records occasionally were incomplete, and some datasets were more detailed than others.

Appendix B shows the NWS weather records of 2002-03 winter storms for the ATRC's project sites across northern Arizona. Unfortunately two sites have data gaps, which are denoted in the tables. One site record sheet was lost for December, a month with significant snowfall across the I-40 corridor. One other site, at Blue Ridge, generally did not record snowfall on weekends, and they also did not record data on several occasions when power was out. Apart from these gaps, the weather records provided a complete picture of the snowfall for the winter. These figures are tabulated in Appendix D, which correlates the extent of research snowplow operational activity relative to each area's snowfall totals.

Other Project Records – Crash Data

One other research area of real significance to the program is the history of winter storm-related crashes and their costs. The information presented in Chapter III of this report was assembled from key resources within ADOT, and represents the history of accidents and their human and financial costs. The primary resource is the 2002 annual edition of ADOT's *Motor Vehicle Crash Facts for Arizona*[4] from the Traffic Engineering Group's Traffic Records Section.

The 2002 annual report and several previous editions provided the primary statistics on crashes, including the lives lost and the injuries from crashes in winter roadway conditions in Arizona. These reports also provide the annually adjusted National Safety Council crash cost estimating figures, which are used to assess the economic impacts of these losses.

ADOT's Equipment Services and Risk Management sections provided other records on the costs to ADOT of snowplow repairs. These summaries of accidents and repair totals were utilized in Chapter III of this report also. As noted therein, the figures are not necessarily complete at the present time, due to unresolved claims and to delays in the distribution of internal charges.

It should be noted that during the five winters of this advanced snowplow field research, there have been no accidents involving the research snowplows during any project activities.