XI. ON-BOARD SYSTEMS: 2002-03 OPERATIONS

REAL-WORLD TESTING

The fundamental ATRC research approach described in the previous section called for the two driver-warning concepts to be deployed in the field as off-the-shelf aftermarket enhancements for the snowplowing environment. Both were relatively simple and durable systems that were available on the open market for commercial transport fleet use. The suitability of collision warning radar and of infrared night vision for snowplowing activities could only be established by a real-world field testing program.

Figure 23. XVision Snowplow F235 Refuels at Little Antelope Camp

The ADOT-ATRC evaluation program depended on achieving maximum exposure for as many snowplow operators as possible, during an entire winter in the high country of northern Arizona. The key features, baseline performance, and safety benefits of the two systems had been demonstrated, and were clear to all involved, but the systems' abilities and reliability had yet to be proven in Arizona's severe winter storms. This could only be done through the long-term deployment of the two warning systems in the hands of experienced ADOT operators, on the most challenging snow plow routes in each district.

Group familiarization, training and evaluation surveys had been practical in earlier winters for the Caltrans and 3M infrastructure-based guidance systems. This was not practical for the Year Five evaluation of on-board systems, due to the wide dispersal of the project plows and to the minimal level of orientation and training needed for driver-assistance systems in general.

As noted earlier, the CWS and IR systems did, in fact, require varying levels of warning display interpretation, and both therefore required some orientation, if not formal training. This was done at the Org level, with materials supplied by the vendors and ATRC, and for the primary operators it was generally effective. As a result, these units could be deployed as they came on line, and they were put into operation as the storm season required. In most cases, at least some familiarization runs were made by the drivers before the first use of the systems in winter storms.

Operational Usage

As was indicated in previous sections, the seven warning on-board systems deployed by ADOT across northern Arizona were given a thorough operational field trial, despite a below-average winter snowfall total. While the test units in some cases were not installed until January or even early February, the systems were in operation during snowplowing activities on 140 use-days of the winter, as summarized from the PECOS records in Table 7.

Table 7. Phase Three Activity Summary for Seven Research Snowplows

Intelligent Vehicles / Snowplow Guidance Research								
Project 473 Winter 2002 – 2003								
PLOW DATA	**F277**	**F326**	**F235**	**F342**	**F291**	**F340**	**F269**	**Sum**
MAINT ORG	Kingman	Seligman	Ltl Antelope	Gray Mtn	Flagstaff	Winslow	Chambers	
PECOS Reports	*12*	*13*	*72*	*61*	*33*	*40*	*16*	*247*
System	XVision	Radar	XVision	Radar	Radar	XVision	Radar	
Primary Route	I-40	I-40	I - 17	US 89	I-40	SR 87	I-40	
Mileposts	54 – 72	121–146	335-340	420-440	185-230	317-290	347-360	
Installed	03-Dec-02	22-Jan-03	07-Feb-02	21-Sep-01	14-Jan-03	03-Dec-02	04-Feb-03	
Plowing Activity Days & Miles Summary								
Total Miles	1,729	1,830	10,871	8,484	4,452	6,863	3,021	37,250
Total Use-Days	6	10	39	32	20	22	11	140

The total number of days of plowing activity usage, and the more than 37,000 miles driven with the warning systems in service, are very significant. The average utilization of the seven project snowplows was approximately 5,300 miles of operations. This activity reflects a season of tests involving some 15 primary operators, and perhaps a dozen more occasional drivers.

The field supervisors and the supporting shop technicians also gained significant experience and awareness of the two on-board warning technologies. For ADOT forces in northern Arizona, this degree of exposure to new concepts provided a positive preview of future vehicle enhancements for driver safety, even though not every expectation was met in the brief season of testing.

DEPLOYMENT PLAN CONCERNS

There were a certain number of issues that arose through the winter with regard to the project's system deployment and evaluation plan as formulated by ATRC and the research TAC. Some of these issues were beyond human control, such as the weather across northern Arizona. Others were in the hands of remote third parties, as some of the "off-the-shelf" commercial units were not available in a timely manner for a consistent rollout at the beginning of the 2002-03 winter. The ADOT procurement process, which involves both procedural and human factors, also impacted the orderly and timely execution of the deployment plan.

The incremental deployment of the units across the region had some impact on how consistently each group of drivers would be introduced to the system on their snowplow. In each case, the assignments of the warning systems were based on the typical visibility conditions encountered on the plow route, and on the type of truck and the experience level of the drivers assigned there.

The snowplow operators were the key individuals for the ADOT evaluation process, and their buy-in was essential. However, even if all of the other selection factors were in harmony, not every driver welcomed the opportunity for testing.

Even with seven snowplows in the field, the operator pool for the evaluation was very small. Generally each plow on a given route had two primary drivers assigned to it, with perhaps one or two others on a backup list. Because of the wide range of factors among operators as to their experience, training, age and attitude, the opinions and interest levels varied between the Orgs, and even in the cabs of individual plow trucks. In a few cases the day and night drivers were polar opposites in their attitudes toward the night vision or the radar.

Driver acceptance of each new system varied. Some saw the systems as ideal solutions to their low-visibility operating problem, but others felt that their attention was already overloaded with plow controls, instruments, radios, warning signals, and other distractions. The snowplow route location, traffic, terrain, weather, as well as personal attitude and level of confidence, all were factors in driver willingness to use the warning systems and to balance their safety advantages with their limitations. Some drivers already had concerns about the sensory overload in the crowded, noisy cab of a snowplow operating in near-zero visibility storms and heavy traffic.

For a few of the operators, the system performance was not consistent enough to trust it fully, and any doubt about the meaning or the urgency of the warning message was seen as a negative factor. This was true for the CWS radar, which required the driver to react quickly to the alarms and warning light display. The EVT-300 was prone to false warnings in specific situations such as bridge structures or roadside signs. It was also true for the infrared system, where the snow buildup on the camera lens caused fading of the screen image, which effectively reduced the XVision's warning functionality. In this case, the problem caused driver satisfaction ratings to drop significantly over the winter.

Operator acceptance of the two on-board systems was measured by ATRC in a series of surveys over the season. The drivers' views on their systems are discussed in the following section of this report, and the end-of-season survey results are included as Appendixes G and H.

XVision – Operational Issues

Based on the initial XVision installation on F235 at Little Antelope in February 2002, and the TAC stakeholder demonstration that followed in May, outlooks were positive and expectations were high for the coming winter. Over the summer, minor concerns arose in occasional night operations with plow F235 that became larger issues when the 2002-03 winter began and all three units were in operation.

Early comments on the XVision system were positive from all three districts. Drivers regularly reported sightings of animals, pedestrians, and even birds along the roadway, long before the headlights illuminated them, but reports were mixed with regard to rain, fog, and light snow. As noted previously, Bendix had initially warned that these factors would reduce the contrast and clarity of the thermal image as read by the infrared camera. But as operations progressed into the storm season, a basic concern with the system's winter performance began to grow.

A key challenge for winter applications is the system for lens heating to prevent snow buildup from obscuring the camera's view. Although tested extensively in the Bendix labs and in Canada, the heater was found to be vulnerable to extreme cold and wind chill factors.

As noted by Bendix in project planning discussions, passive-infrared is not specifically designed for continual service in high moisture conditions like snowplow vehicles can and do experience. The Bendix lens heater is a significant improvement but clearly is still not enough to overcome all the moisture scenarios that plow trucks encounter.

Figure 24. Freeze, Thaw, and Refreeze: the Camera Window Heating Element

The primary problem had to do with the lens heater element, as the single biggest complaint was snow being packed into the lens of the camera. While the drivers expected to clean the infrared camera whenever they stopped to clean their wipers and lights, they also expected the heater to be effective. On some plow routes there were few opportunities to pull off safely to clean the IR camera – which was masked by snow more rapidly than the driving lights and wiper blades.

With regard to the heater performance, the two new off-the-shelf XVision units did not seem to have problems as frequently as did the F235 prototype, for which Bendix exchanged several heating elements over the winter season. On occasion the lens temperature was measured at over 110 degrees (F), but at other times the drivers said it simply would not heat up to the touch. As shown in Figure 24, the heater did melt snow that built up within the recessed lens barrel, but it was unable to keep up with rapid accumulations. This picture also shows the threat of ice buildup to the exposed camera wiring.

The source of the problem was not identified, but it may have been the calibration of individual thermostats or the capacity of the heating element. The larger issue was the combination of cold, moisture and wind effects, which were more than the heater unit could effectively deal with. Driving into the wind in an oncoming storm aggravated the problem, and driving with the wind reduced it somewhat. The moisture level of the snow and the wind speed and direction were other significant factors. Slush spray from the plow blade was also a key problem area.

Other issues with the system were also generally related to the design of the camera window and lens barrel assembly. As Figures 19 and 24 show, the lens window is recessed, which creates a pocket for snow to quickly accumulate. Road film may also accumulate there; Figure 19 shows a gradual buildup of deicing chemical on the silicon disk of the lens window. The focal length of the XVision camera is approximately 80 feet, so dirt and bug parts do not block the image, but the lens pocket design seems to collect airborne material. ADOT drivers also reported problems in the rain; they experimented with commercial dispersant products but saw little improvement.

While the XVision camera mounting design seems exposed to damage, it is basically designed to be used by over-the-road transport tractors and so would usually be mounted within a cab fairing. Nonetheless, the lens itself has an exposure problem. Bendix worked with its contractors and was able to provide several shield options for truck cab rooftop applications, and ADOT selected one shield design, installed in January, for all three of the project snowplows (Figure 21).

As noted before, XVision was designed and tested by Bendix as an all-weather system but was not conceived specifically for severe storm use. It must be emphasized that while Bendix was never in a position to modify the basic design based on Arizona service observations, they have continually offered new approaches to solve perceived problems in the field. This support has included several replacement lens heater elements, the provision of camera shields, and the upgrading of F235's HUD with the new production LCD screen. There was frequent technical collaboration on display mounting hardware and on lens cleaning materials and techniques, and ADOT and Bendix continue to evaluate new approaches to the remaining issues.

EVT-300 – Operational Issues

The Eaton VORAD collision warning radar did not suffer from the snow-related problems that frustrated drivers of XVision-equipped snowplows during this Year Five winter of the project. On the other hand, the confidence issues discussed earlier were a concern for the EVT-300 test program. The level of familiarization and driver focus required to successfully utilize the CWS warnings in poor visibility was significantly greater than for the infrared display screen. This led some drivers to doubt and even to ignore the warnings; a few avoided using the system at all.

The training material for the EVT-300 system spelled out a number of key concerns, primarily in regard to the potential for false alarms or missed warnings. The system's narrow radar beam and its cutoff of warnings outside the predicted vehicle path provided sensitivity and accuracy only within that critical warning zone, and operators therefore had more confidence in the EVT-300 when it sounded an alert. However, some drivers, especially alternates, were unable to adjust to learning the predictable gaps in radar beam coverage for areas of hills, dips and curves. Nor were they comfortable with the predictable false warnings from overpasses, signs, and roadside features. The blind spot radar, while very popular, was also for a few drivers just one more source of uncertainty in stressful conditions and limited visibility.

There were a number of concerns about how well the Doppler radar would respond to specific targets ahead, such as animals or people, especially after a December 2002 incident when a tractor-trailer rig killed ten elk on I-17 just south of Flagstaff. Eaton and ATRC provided clarifications that the radar response to objects depends on body mass, metal content, position, and movement. For animals running across the 12-foot lane, the response window was too brief for the CWS, or even the human eye, to give a consistent warning.

Another significant driver concern was stationary objects in the roadway. Because of the warming system parameters, the EVT-300 is designed to respond immediately to a stationary object within a range of 220 feet. Considering the travel speed of the host vehicle, and the need to identify the target visually, Eaton's training material recommends reacting immediately to the characteristic double-tone warning for a stationary or very slow-moving vehicle, which would always be a dangerous situation. Reaction time is critical, even at slower snowplowing speeds.

The driving challenges, distractions, and stress factors varied on each plow route and for each individual. A few of the snowplow operators could not fully adjust to using the CWS concept under stressful low visibility conditions. Other crews with more experience using the EVT-300, such as snowplow F235 at Gray Mountain, were comfortable with the radar system and were willing to rely on it more.

SUMMARY OF 2002-03 OPERATIONS

The seven project snowplows accumulated 140 days of winter maintenance operations, and more than 37,000 miles of operational service in the Phase Three 2002-03 winter evaluation program. In this phase, at least two dozen snowplow operators and numerous support personnel received varying degrees of exposure to infrared night vision and collision warning radar.

As described in the preceding discussions of operational issues, individual driver preferences were significant in the evaluations of both the radar and the night vision warning systems. Sometimes two back-to-back primary operators on a snowplow were in complete disagreement. The judgments of the local Org supervisors and superintendents, based on all of their drivers' comments, may ultimately be the districts' primary decision basis for any further applications of these on-board warning systems.

It is noteworthy that while the I-40 Corridor received only about 55 inches of snow in the season, each of the test snowplows still was out on the road for an average of approximately 5,300 miles of operations. If all seven test units had been commissioned in October before the first storm, the research fleet would potentially have had 49 combined months of plowing activity; their actual combined activity total was roughly 33 months.

Projecting these on-the-road utilization figures to an "average winter," the normal combination of 100-plus inches of snowfall and full availability for the seven research snowplows could be expected to result in well over 100,000 miles of field service for the project's two commercial on-board warning system concepts.