XIII. DEFERRED RESEARCH TASKS: RESOLUTIONS

OTHER GOALS: SMARTCRUISE BY EATON VORAD

As described earlier in Chapters VI and VII, one of the key elements of the EVT-300 collision warning radar system is its SmartCruise adaptive cruise-control feature. From the beginning, ADOT and ATRC intended to evaluate SmartCruise as a key element of the total radar-based driver safety package offered by Eaton VORAD.

ATRC's series of project reports have already discussed the various issues involved with the use of the CWS system, which required a rooftop mounting position for the antenna because of the height of the standard ADOT snowplow blade. The SmartCruise feature could not be tested during the previous or current winters of the project because the rooftop antenna and the plow blade prevent the use of the system as designed by Eaton VORAD.

The F342 snowplow from Gray Mountain was the original dedicated ADOT-3M-Eaton research vehicle, and logic and practicality dictated that SmartCruise be tested on this truck. This 1999 Mack was delivered with the factory cruise control system, so that the EVT-300 could be adapted to it. However, a variety of SmartCruise implementation issues arose with regard to the type of engine computer and the installed version of Mack's engine control software. The problems were ultimately worked out with close support from Eaton VORAD, Mack Truck, and both Flagstaff and Central ADOT Equipment Services, although it took considerable time to do so.

The first hands-on upgrades to F342 began in late December, but engine computer and diagnostic issues were immediate obstacles. Diagnostic issues and procedural concerns delayed the process further. The SmartCruise was fully commissioned in March 2003, with driver instruction and familiarization as the first step, followed by system testing.

SmartCruise Summer Evaluation Plan

With SmartCruise finally installed as part of the F342 CWS radar system, there were operational issues that precluded immediate training and testing. As the late winter progressed in northern Arizona, snowplowing activity continued through April, and basic roadway maintenance efforts were the initial focus at the Orgs after the plow blades were removed and stored for the summer.

The Gray Mountain plow operators were introduced to the SmartCruise functions in March when the feature was commissioned. They were asked to test it as opportunities arose during the early summer agenda of roadway maintenance operations in the area. With guidance from the project TAC, ATRC coordinated with Gray Mountain to conduct road tests of the system in mid-July.

The ATRC test plan involved both objective and subjective evaluations. The primary goals were to road-test the SmartCruise adaptive cruise control system in highway traffic, and to attempt to measure the consistency and accuracy of its performance. Although the EVT-300 system would monitor its own performance internally, checks on validity of the indicated performance figures were required. ATRC staff would ride with the plow operator for a series of test runs, taking measurements and recording observations. On a second level, the driver feedback and passenger observations would be documented.

ATRC developed a set of criteria to measure and monitor the SmartCruise system performance. The four primary objective criteria were:

- Preset speed control – accuracy.
- Following distance – consistency.
- Following distance – accuracy.
- Effect of vehicle sizes on following performance.

The subjective evaluation would involve a variety of observations on performance, as follows:

- Smoothness – engagement and disengagement.
- Positive driver overrides – brake & accelerator.
- Operation in curves.
- Operation on grades.
- False warnings from roadside objects.
- Response to vehicles suddenly cutting in (consistent & appropriate).
- Effect of vehicle size on system response when cutting in.
- Effects of inclement weather – dust, fog, rain, snow, mud, heat, cold.
- Warnings – type and intensity.
- Operator confidence level.
- Operator fatigue factors.
- Overall satisfaction – suitability for driving tasks.

With cooperation from the Flagstaff Equipment Shop and the Gray Mountain Org, the ATRC's SmartCruise evaluation was conducted on July 17. The test plan was to initially calibrate all of the EVT-300 system elements at the shop, and then to take the snowplow out on Interstate 40.

ATRC staff received valuable support from TAC members for the tests, including the Flagstaff District of the DPS, which provided a Stalker speed radar gun to verify both the snowplow and target vehicle travel speeds. ATRC obtained a Bushnell Lytespeed 400 Infrared rangefinder from ADOT Natural Resources to confirm the target distances.

The Flagstaff Shop provided its ProLink portable diagnostic system as the primary in-cab tool to display real-time SmartCruise performance data from the EVT-300's onboard computer. The hand-held systems provided crucial backup data when the ProLink unit failed during the testing.

SmartCruise Testing Results

After confirming system functionality, F342 made several round trips on a 25-mile stretch of I-40 east of Flagstaff, between Walnut Canyon and Two Guns. This section gradually rises in elevation, with a series of long grades in rolling hills as I-40 climbs west towards Flagstaff.

During multiple runs in both directions, the snowplow was run on its Mack cruise control system at speeds of 55 to 65 miles per hour, and the SmartCruise was tested both by overtaking and then tracking slower vehicles, and by "locking on" to faster vehicles that passed. A series of four test runs were made, during which several targets were acquired and followed for five to ten miles.

The ATRC used the ProLink display to record the EVT-300's speed and distance measurements, and also confirmed them with the hand-held radar gun and rangefinder. This was eminently

successful in two ways; on initial runs the two sources of data provided nearly identical readings. After two runs, when the ProLink failed, the tests were therefore able to continue using the hand-held units with a high degree of confidence.

Overall, both the objective and subjective results were considered to be a complete success by the plow operator, by the Flagstaff Shop and by ATRC. The ProLink diagnostic tool showed that while the EVT-300 might register a brief target loss when entering a curve, as expected, the SmartCruise held smoothly to the acquired target. There were no problems with false warnings of roadside objects on the Interstate. The system also worked very well on both upgrades and downgrades. Speed changes occurred while following vehicles on hills, but the following distance remained consistent while the target vehicle changed its speed. There was no observed problem regarding vehicle size, as several vehicles were tracked with equal results.

Figure 25. SmartCruise Antenna and Hand-Held Test Equipment

As noted above, the evaluation included four test runs during which SmartCruise tracked target vehicles of varying sizes, types and speeds. In each situation, the four primary objective criteria were met, as described below.

- Preset speed control – accuracy: The Mack cruise control was effective in holding speeds within 1 mph, with a slight variation on grades. Plow F342, with a manual transmission, was able to hold speed accurately on its factory cruise control. There was no apparent loss of accuracy with the VORAD SmartCruise engaged to acquire and follow a target vehicle.

- Following distance – consistency: Following distance varied from 250 to 310 feet, as based on travel speed and the system's following-time interval setting. Ranges fluctuated by 10 to 15

feet. The system follows at a set separation interval in seconds, based on travel speed. Even in hilly terrain the SmartCruise maintained a fixed following (time and) distance relative to targets.

- Following distance – accuracy: The ProLink speed readings displayed error rates of only +/- 0.2 to 0.5 mph. These rates increased up to +/- 1.5 mph on grades. Range errors displayed were only +/- 15 feet. The ProLink and hand-held figures corresponded very well.

- Effect of vehicle sizes on following performance: No significant issues were identified, and consistent results were observed with several vehicle types. Vehicles tracked included a compact sedan, a compact pickup, and two tractor-trailer rigs – a cargo trailer and a tanker.

Subjective evaluations of SmartCruise were also positive. For the snowplow driver, there were no issues with the system acquiring a target vehicle or disconnecting. Driver overrides also were basically seamless. As a result of the day's test runs, the operator responded positively to most aspects of the system. While he had not previously tried the SmartCruise more than a few times, the test driver said that he was impressed and felt comfortable using it after the day's activities. He also said that it was likely to improve his safety and driving performance on the highway.

Appendix I contains the testing and observation records of the July 17 testing on I-40, and the complete evaluation activity results for the EVT-300 SmartCruise feature as discussed here.

OTHER GOALS – TECHNOLOGY TRANSFER

Figure 26. Gray Mountain and Kingman Plows: ADOT Equipment Roadeo

With the conclusion of the 2002-03 winter season, there was a great deal of interest in the project results, both among TAC members and for other agency partners and stakeholders. With all seven installed systems fully functional and with no snow in the forecasts, the TAC's attention turned to planning for the next winter. This focus also included disseminating more information to interested partners on the concepts and benefits of the two low-cost warning systems.

As recommended by the TAC membership, the ATRC displayed the project's concepts at two significant events in the fall of 2003. The first of these stakeholder outreach events was ADOT's annual Arizona Equipment Partnering Safety Roadeo. This exhibition includes safety training, operator competitions, and equipment displays. The event was held in September at the Arizona State Fairgrounds, and the ATRC participated with a display table and literature.

Two of the project's research snowplows were also exhibited during the Roadeo, as shown in Figure 26. Snowplow F277 was driven down from Kingman to display the XVision system. The second plow was F342 from Gray Mountain, equipped with both the EVT-300 radar and the 3M tape guidance system. ATRC also laid out 80 feet of magnetic tape to illustrate Lane Awareness System concepts to the event visitors.

The statewide Equipment Roadeo was a valuable opportunity to display both on-board systems and to market their advantages to hundreds of maintenance personnel from other ADOT districts around the state, as well as maintenance and equipment services managers in the Phoenix area. Other interested Roadeo visitors included a contingent of transportation department personnel from New Mexico.

Figure 27. Chambers and Winslow Plows: Four Corners Conference

The second significant outreach event was the annual Four Corners Maintenance Conference, held in Cortez, Colorado in early November. The ADOT Holbrook District was the conference host for 2003. As a core partner in this research project, the district provided its two research snowplows for the event. These were F269 from Chambers, with the Eaton VORAD CWS radar system, and F340 from Winslow, with the Bendix night vision system.

About one hundred maintenance personnel attended this event from Colorado, New Mexico, Utah and Arizona. The ATRC project staff made a brief slide presentation, and also assisted the ADOT plow operators with a display table at the outdoor exhibit area.

Both of these well-attended maintenance-oriented events involved operations staff, equipment operators, and senior managers. For the research project and its sponsors, they were both

excellent opportunities to display the new warning system concepts, and to showcase Arizona's commitment to improving safety for its snowplow operators and the public.

OTHER GOALS: SURVEY ON LOW-VISIBILITY PLOW ROUTE MILES

One of the project's long-range goals was to develop a consistent estimate of the areas of the state highway system that regularly experience severe visibility problems in winter storms. There are numerous highway corridors in Arizona where visibility frequently is obscured due to blowing and drifting snow in winter, or in fog and heavy rain year-round. Based on terrain, elevation, and prevailing weather patterns, highways in certain areas may be restricted or closed frequently in severe winters. These low-visibility areas are a major challenge for the ADOT snowplow operators, and any road closure in bad weather also creates severe problems both for the public and for public safety agencies.

This research project, guided by the TAC members, first initiated an impaired-visibility survey as part of the effort to determine deployment factors for the costly infrastructure-based Caltrans and 3M snowplow guidance systems. Because of the high cost of the roadway magnetic media, it was clear that only the worst whiteout or low-visibility areas might justify the installation of systems that required embedded roadway materials.

One of the program tasks that were assigned to Northern Arizona University in the project's third winter (2000-01) was to conduct a comprehensive survey of ADOT senior managers as to the potential to deploy the two guidance systems under evaluation at that time. This survey effort addressed winter maintenance problems and perceptions across ADOT management ranks. One of the key goals in that survey was to identify all of the low-visibility and whiteout areas on the state highway system.

The NAU survey effort, while extensively involving the TAC members, was more difficult than expected. The NAU team found that there were several related measurements used by ADOT in winter maintenance planning and budgeting, and local perceptions varied across the state as to what measure was most significant. The research project's definitions of impaired and whiteout visibility levels, as developed by the TAC, were also subject to regional semantic debate.

The districts had different perspectives on the severity and frequency of visibility impairment, and of plowing difficulties. Other local or regional factors were also involved, such as long-term average winter snowfall totals, frequency and severity of storms, types of plowing equipment in use, and the experience level and turnover rate of the local snowplow operator pool.

The NAU project team worked extensively with the TAC, in particular the Flagstaff maintenance staff, but the first survey results were inconclusive, as described in the 2000-01 project report. [2] As a result, the visibility survey was reformatted and the parameters were redefined. It was sent out only to the ADOT District Maintenance Engineers, in order to achieve more consistent results. Despite these and other follow-up efforts by NAU, the project's TAC members found the results of the second survey were still not consistent, as described in the 2001-02 report. [3]

Visibility Survey Resolution

Finally, the ATRC made a third attempt to resolve the survey issue, as the project wound down after completing the on-board system evaluations in the 2002-03 winter. Since NAU was no

longer on the project team, the ATRC and the TAC agreed to focus the survey differently. The definitions of whiteout and impaired visibility, however, were not changed. One clarification was that on-board systems will apply to entire snowplow routes, not just to extreme whiteout areas that might extend for only a mile or two, where magnets or 3M tape might be considered.

Each district was surveyed on the basis of milepost distances along route corridors. Because infrastructure cost is not an issue for CWS radar or for night vision, the length of the highway corridors with impaired visibility and the number of plow routes with visibility problems are the key decision factors for possible future deployments. The real issue at the local level would be how many snowplows might need these types of warning systems.

Table 9. Final Results of the Statewide Winter Visibility Survey

ADOT Winter Visibility Survey: Highway Corridor (Milepost) Distances

ADOT Maintenance District	Whiteout Visibility Miles Total[(1)]	Reduced Visibility Miles Total[(1)]	Total Extent w/ Impaired Visibility	Total of Plow Route Miles in District	Total of All Highway Miles in District	Impaired Percent of Plow Route Miles	Impaired Percent of All Route Miles
Flagstaff	63	97	160	776	776	21%	21%
Globe	117	179	296	804	919	37%	32%
Holbrook	130	215	345	833	833	41%	41%
Kingman	100	140	240	385	530	62%	45%
Phoenix	6	0	6	20	379	30%	2%
Prescott	146	78	224	387	572	58%	39%
Safford	47	48	95	675	804	14%	12%
Tucson	11	18	29	112	840	26%	3%
Yuma	0	0	0	0	562	0%	0%
State-wide Totals	*620*	*775*	*1,395*	*3,992*	*6,216*	35%	22%

[(1)] **Whiteout Visibility Conditions**: Unable to continue plowing; cannot see beyond the hood or make out any surroundings. May last 15 to 20 minutes or more. Occurs 3 or more times each winter season: Oct 15 - Apr 15.

[(2)] **Reduced Visibility Conditions**: Plows have to slow significantly, even occasionally stop. May last 15 to 20 minutes or more, but is not bad enough to be considered a "white-out". Occurs 3 or more times each winter season: Oct 15 - Apr 15.

Notes - Route or Corridor miles are the total length of the low- or zero-visibility section of the corridor, as defined by the starting and ending mileposts. Plow Route miles are the normal patrol route segments where plows are always assigned for an exp

Survey data updated & verified by ATRC during months of June-August 2003. Rev: 08-15-03

Another significant change to the survey was to identify not only the extent and distribution of the two impaired visibility roadway categories, but also the total extent of the assigned snowplow routes in each district. The goal was to identify the proportion of snowplowing routes for each district and for the entire state highway system, and to also determine the extent of the impaired or whiteout zones on those snowplow routes. Winter storm patterns and severity are relatively fixed in the long term, and these results will support winter maintenance planning at all levels.

The key information sources were still the district maintenance managers. ATRC presented the new survey to all of the districts at a maintenance retreat in mid-June and expressed the need for consistent responses. By providing worksheet files and large paper maps for each district, the ATRC ensured that the information could be verified as it was received, and then summarized.

This approach was successful, and the ATRC had received and reconciled all of the responses by the end of July. As shown in Table 9, the third project survey found that nearly 4,000 miles, or

60 percent, of the 6,216-mile state system are designated as snowplow routes for major winter storms. Based on this locally-sourced information, almost 1,400 miles of highway have impaired visibility in a typical snowstorm, which is more than 20 percent of the entire state system. More than half of those sections will experience whiteout conditions.

It should be noted that there will always be possible inconsistencies among the individual district perspectives on how they define impaired visibility plow routes, but each district has its own local circumstances and challenges to assess. The research project's goal has been to develop information on the potential of the two on-board driver warning systems (as well as for the roadway-based systems) so that each district maintenance team can determine whether, and where, these concepts would be of real value to them.

As noted above, each district was given large maps to help work out their impaired and whiteout visibility zones on each highway corridor in their area. These maps supported the tabulation of the milepost limits for each low-visibility route segment, and the color-coding clearly showed regional trends based on terrain or storm weather patterns as well.

While the scale reduces its clarity, a statewide map (Figure 28) was created to illustrate the extent of the visibility problems for the ADOT snowplow operators across Arizona.

The complete tabular and graphic results of the project's snowplow impaired-visibility survey are included in Appendix K of this report. Both a visibility classification map and a route summary table are provided for each of the ADOT maintenance districts.

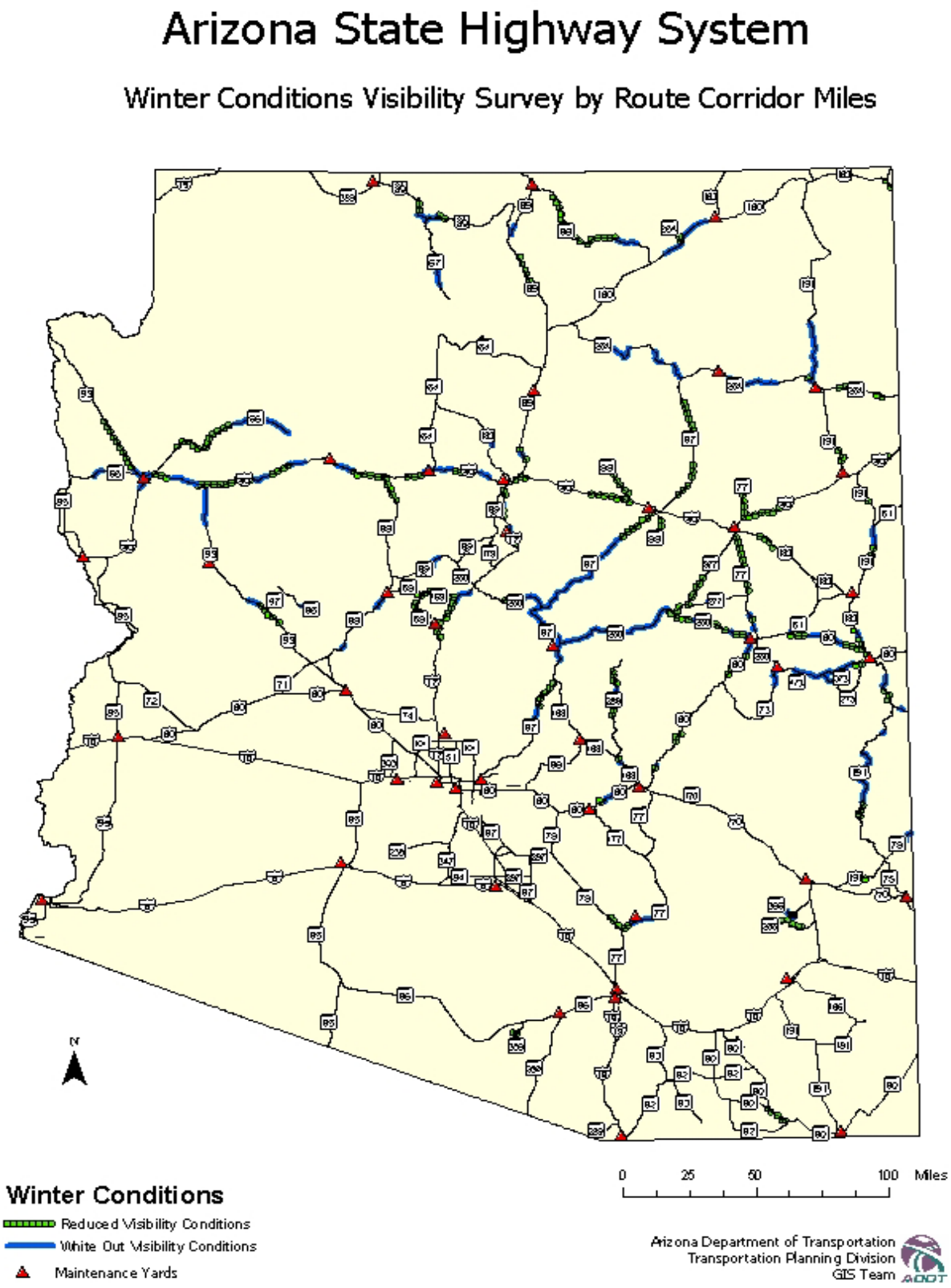

Figure 28. Impaired Visibility Snowplow Routes