

VIII. BENDIX XVISION INFRARED CAMERA: THE SYSTEM

SYSTEM CONCEPTS

Bendix Commercial Vehicle Systems is a major source of truck and automotive components in the United States and overseas. While several other suppliers have concentrated on security-system markets such as law enforcement and the military for their low-light vision enhancement systems, Bendix has taken the initiative in marketing their XVision system to the heavy transport industry in the United States.

Commercial trucks and buses make up a large component of the traffic volume on the nation's highways, and at night the proportion of heavy vehicles on the road increases significantly. Bendix literature describes XVision as "the first infrared night vision system for commercial trucks and buses that allows drivers to see farther, react sooner and drive smarter."

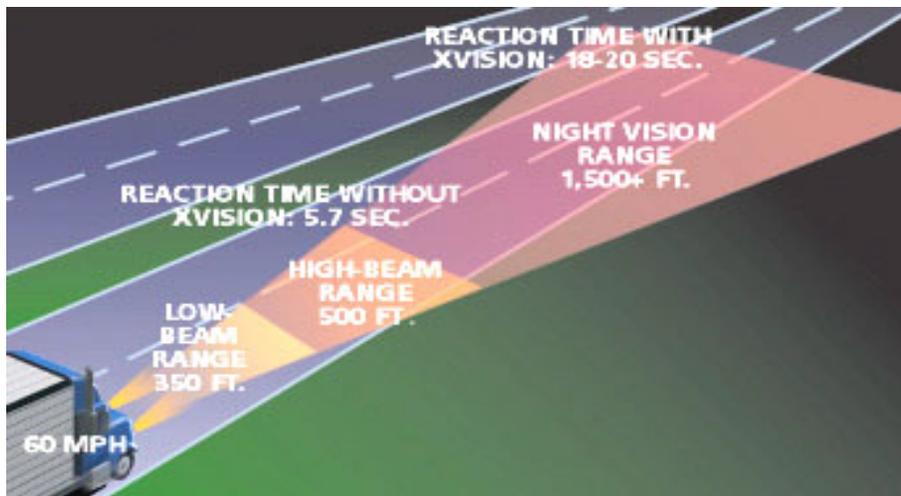


Figure 14. XVision Enhancement of Reaction Time to Roadway Hazards

[Graphic by Bendix Commercial Vehicle Systems LLC]

The Bendix XVision thermal imaging night vision system is a passive-infrared design, which requires no external light source. Passive-infrared technology reads the different heat signatures, or levels, of all objects in the camera's field of view and displays them as black-and-white images on a display screen. Every object, including the roadway, has a heat signature, and animate objects, such as deer and people, show up boldly as high-heat sources.

XVision is marketed not as a warning system but as collision avoidance information technology. As visibility is reduced, so are reaction times and overall road safety. The XVision system has the ability to extend the driver's range of vision far beyond his vehicle's headlights, which are only effective for 300 to 500 feet. Thermal imaging night vision can increase a driver's vision range to three to five times beyond the vehicle's headlights, out to 1500+ feet. With such an increase in effective vision at night, driver reaction time at 70 mph can increase from only five seconds with high beams to as much as 15 seconds with night vision, as shown in Figure 14.

The key advantages of the passive-infrared system are increased vision distance and improved recognition of road hazards. The design is most effective at night to detect and identify animals, pedestrians, work zones, turnouts, road debris, poorly lit vehicles and slow or stalled cars. The screen image is not affected by glare from oncoming headlights, allowing the driver to not only see farther, but see better.

The Bendix XVision system has been marketed nationally since 2001. A number of new features have been phased in during the past two years. The primary market for Bendix is seen to be heavy commercial trucks, but the night vision concept has extensive potential for specialty fleets, including emergency and highway maintenance vehicles such as snowplows.

ADOT EXPERIENCE WITH NIGHT VISION

ADOT had no real practical experience with passive-infrared night vision systems before the advanced snowplow project investigated the subject in mid-2001. Initially, the engineering team of ADOT's Equipment Services Group suggested that the concept be evaluated. Following up with supplier contacts, ATRC arranged for a presentation by the local Bendix representative. As a result of this meeting, the research TAC members agreed that the concept should be evaluated.



Figure 15. Original XVision Camera Installation on Snowplow F235

While an ADOT evaluation agreement and commercial pricing were generally established in late 2001, the XVision system was not completely ready for the market. Bendix could not provide a unit to ADOT before the 2001-02 winter was well along. The research project went ahead with the joint Caltrans ASP plans for Phase Two(b), with night vision remaining a secondary concern.

The XVision system was eventually delivered to ADOT in late January, and it was assigned to snowplow F235 at Little Antelope Camp on Interstate 17 in the Flagstaff District. XVision was finally installed on an ADOT snowplow in February 2002. However, commissioning problems

delayed the first tests. Worse yet, shortly after the installation, this truck was taken out of service for unrelated equipment upgrades at the Phoenix shops, which were not finished until April.

As a result, no practical testing could be done with Bendix XVision until the following winter season began, in late 2002. However, as the system installation was refined over the spring, the project stakeholders maintained a high level of interest. In May, a demonstration was arranged for the TAC members with snowplow F235 at Rim Camp, on highway US 89A near Flagstaff.

THE BENDIX XVISION SYSTEM

XVision utilizes an externally mounted rooftop infrared camera, which senses relative heat levels of objects in the field of view. The camera can measure temperature differences as slight as 0.4 degrees Fahrenheit, and it processes the signals electronically to produce a virtual image on a flat-screen display mounted near the driver's line of sight. The system displays a thermal map of the forward view, with relatively warmer objects as brighter images, and cooler inanimate objects show in shades of gray (see Figure 18).

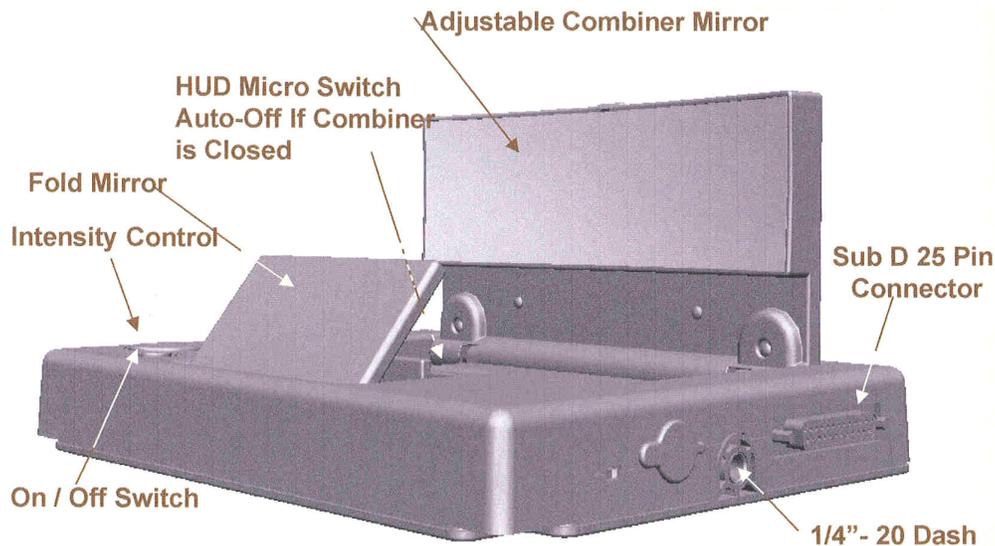


Figure 16. Original XVision Head-Up Display Unit (HUD)

[Graphic by Bendix Commercial Vehicle Systems LLC]

The Bendix XVision system was originally packaged with a head-up display unit (HUD) with folding mirrors. The infrared image is viewed on the combiner mirror (Figure 16). However, ADOT found that heavy vibration of the snowplow truck reduced the dual-mirror system's effectiveness. The current unit is sold either with the HUD unit shown above, or with a liquid-crystal display (LCD) flat-panel display screen (Figure 17). The driver needs to glance at the screen only occasionally, as a passenger car driver would glance at his rear-view mirror.

A significant option to enhance driver safety with XVision is a rear- or side-mounted low-light camera and microphone unit to monitor the blind spots around the vehicle. This camera shares

the forward night vision camera's display screen, and the driver can easily toggle from one view to the other. Due to icing concerns, this feature was not considered by ADOT for snowplows.

Another option is a selection of protective shields for the XVision camera. ADOT has added a shield for each of the three research snowplows, in order to protect the camera's mounting and aiming hardware. As shown in several figures, the basic infrared camera, wiring harness and mounting system are exposed to damage from road debris and other hazards. The camera shields that later were developed by Bendix are not completely enclosed, but they do protect the camera unit (but not the lens window) against damage from the front and sides (see Figure 21).

PASSIVE-INFRARED SYSTEM DESIGN

The XVision camera and its original HUD display unit are a self-contained system. For the new flat-panel display, as upgraded by Bendix, a separate processor unit is required. The infrared camera itself is approximately 8 inches high, 10 inches wide and 6 inches deep. It bolts into the cab roof, and requires an additional one-inch hole for the data cable. The camera and brackets weigh 4.3 pounds. The camera's field of view is 11 degrees horizontal and 4 degrees vertical. The XVision system is capable of detecting temperature differentials as small as 0.4 degrees (F). The system's operational temperature range is from -40 to +140 degrees (F). This passive-infrared system detects electromagnetic energy in the 7-14 micron wavelength region.



Figure 17. Bendix Upgraded Flat Screen LCD Display: Dashboard Mounting

The original head-up display unit (Figure 16) weighs two pounds and is 1.25 inches high, 9 inches wide and 7 inches deep. Because the space in truck cabs varies so widely, the unit is designed for either dashboard or headliner mounting. The HUD is mounted in the driver's line of sight, to provide the same relative perspective of objects as in his normal view.

The new optional Bendix flat-panel LCD display screen shown in Figure 17 (6.8-inch diagonal) has several mounting options, and due to its size, it may have to be offset more from the driver's line of sight. This display screen is eight inches wide, 5.25 inches high and 1.15 inches deep.

The key to functional success of the passive-infrared system is its ability to perform under a range of adverse conditions. The XVision concept depends on a clear field of vision. A camera window that is a 1.3 mm-thick silicon disk protects the infrared sensor system. This disk, which is transparent to infrared radiation, has a scratch-resistant coating to prolong its service life through frequent cleanings.

For winter operations, the XVision camera has an internal heating element that is designed to prevent gradual snow buildup on the lens itself (see Chapter XI, and Figure 24). This internal heater is in the lens bezel, not the silicon camera window, and it is intended to melt snow or ice within the inch-deep pocket formed by the lens bezel and the flat silicon disk. A thermostat activates the heater when the temperature drops below 40 degrees (F).

XVISION - ADVANTAGES AND LIMITATIONS

The advantages of night vision are quite clear, in particular for public safety and public service users in a variety of field conditions. For highway maintenance, one of the primary nighttime activities is winter storm operations. The simplicity of the system is a major advantage; it displays everything in the field of view and it triples the vision range beyond that of headlights. Unlike a CWS radar system such as the EVT-300, night vision requires no interpretation of warning chimes, tones, or lights, and it is not prone to false alarms or erratic detection.



Figure 18. XVision Thermal Imaging Display of Roadway Hazards

[Graphic by Bendix Commercial Vehicle Systems LLC]

There are limitations with the passive-infrared concept. XVision was designed and tested for service in all weather conditions but was not specifically enhanced to cope with severe weather. The nature of infrared detection is that the thermal differential of objects in view is reduced to some extent in fog, rain or snow, which falling at a uniform temperature can create a haze effect over the thermal images on the display screen. Under these conditions, interpretation of some thermal images may not be intuitive.

For operations by ADOT and its partner agencies, the infrared night vision concept is obviously a nighttime resource. The reality is that heavy ADOT vehicles are not operating on the road at night very frequently, except during storm-related maintenance operations. The night vision concept must therefore be justified by storm patrol and snowplowing activities alone.

XVISION SYSTEM - COST DETAILS

The first XVision system was provided to ADOT in a joint evaluation agreement with Bendix. The Bendix XVision commercial rollout took place in December 2001, after a series of pre-production refinements, and in January 2002 ADOT agreed to work as a developmental partner with Bendix on evaluating Arizona's first field unit prototype, and would test any future system upgrades as they were released.

Based on early impressions from the F235 installation, and the TAC demonstration in May 2002, the project initiated the purchase of two additional off-the-shelf units from Bendix for the 2002-03 winter test program, at which time the XVision system was commercially priced at \$3,895. However, the value of the camera shields was roughly \$100 each, and the average cost of the full system installations, at ADOT shop labor rates, was \$800. Considering commissioning and shop troubleshooting labor charges, the average installed cost of each basic XVision system on the three ADOT snowplows was approximately \$5,000.

As described later in this report, system performance was impaired in heavy snowstorms. ADOT and Bendix worked closely together through the 2002-03 winter with the three XVision units to develop and test solutions, some which are still being evaluated in the 2003-04 winter.

A number of ongoing cooperative efforts were made by ATRC and Bendix to refine the system and to improve its performance consistency, primarily dealing with camera lens-cleaning options. The installed cost to ADOT of this additional hardware as of late 2003 has been roughly \$2,000 per vehicle. The washers have been functionally successful in field testing, and the overall value of these changes for night operations will be determined after the 2003-04 winter season.