Division of Research
& Innovation

Early Warning System for Bridge Hits by Tall Load Vehicles

Final Report

Report
CA03-0262
December 2008

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STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT DOCUMENTATION PAGE

TR0003 (REV. 10/98)

1. REPORT NUMBER CA03-0262	2. GOVERNMENT ASSOCIATION NUMBER	3. RECIPIENT'S CATALOG NUMBER
4. TITLE AND SUBTITLE Early Warning System for Bridge Hits by Tall Load Vehicles		5. REPORT DATE June 2003
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Asfand Yar Siddiqui Transportation Engineer California Department of Transportation Division of Research and Innovation 1227 "O" Street, MS-83, Fifth Floor Sacramento CA 95814 (916) 654-6994		8. PERFORMING ORGANIZATION REPORT NO. Caltrans Internal
9. PERFORMING ORGANIZATION NAME AND ADDRESS California Department of Transportation Division of Research and Innovation, MS-83 1227 O Street Sacramento CA 95814		10. WORK UNIT NUMBER
		11. CONTRACT OR GRANT NUMBER In-House
12. SPONSORING AGENCY AND ADDRESS California Department of Transportation Sacramento, CA 95819		13. TYPE OF REPORT AND PERIOD COVERED Final Report
		14. SPONSORING AGENCY CODE
15. SUPPLEMENTAL NOTES		

16. ABSTRACT

The prime objective of the project was to evaluate products offered by two companies. These companies are CYRA and Bridge-Test. Two of their products were evaluated to see if they can server the departmental need to check the bridge clearances quickly and with safety.

17. KEY WORDS Bridge Clearance	18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161	
19. SECURITY CLASSIFICATION (of this report) Unclassified	20. NUMBER OF PAGES 15	21. PRICE

Final Report

Early Warning System for Bridge Hits by Tall Load Vehicles

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Executive Summary

California's transportation system is responsible for moving public traffic and commerce over a vast array of highways. It is easy to recognize the economic importance for moving the public, goods and services as well as maintaining a safe environment for all that use the system.

Many bridge structures, which cross California's State Highway System, are being routinely damaged by vehicles transporting loads in excess of legal height. There is a myriad of implications resulting from these incidents all of which prohibit optimal use of our transportation system while potentially creating unsafe conditions to the traveling public.

Complying with the California Department of Transportation's "Mission" for improving mobility across California, it was the intent to develop an early warning system for bridge hits by tall load vehicles. The intent of the project was to develop two versions of this system. The first would be permanent in nature and this system would be used at bridge locations that have a history of being hit by tall load vehicles. The second version of this system would be portable in nature and will have dual use. The primary use would be to provide security at bridge construction sites. This system will alert construction workers, in advance, working on a bridge of an on-coming tall vehicle. Subsequent usage of this system will be to assist California Highway Patrol (CHP) in checking tall vehicles on the freeway.

While the preliminary work was being initiated, we found out two companies that produce similar products that could help the department in abetting the bridge hits. The products of these companies were evaluated and are a part of this report.

Project Motivations and Objectives

Motivations

Many bridges on the State highway system are damaged every year by vehicles, which carry loads in excess of legal height.

California Vehicle Code Section 35250 defines legal height as follows: No vehicle or load shall exceed a height of 14 feet measured from the surface, upon which the vehicle stands, except that a double-deck bus may not exceed a height of 14 feet, 3 inches. Any vehicle or load, which exceeds a height of 13 feet, 6 inches, shall only be operated on those highways where deemed to be safe by the owner of the vehicle or the entity operating the bus.

Additionally, the California Vehicle Code makes allowances for vehicle operators who wish to exceed the height limitations specified in Section 35250. California Vehicle Code Section 35780 states the following: The Department of Transportation or local authorities, with respect to highways under their respective jurisdictions, may at their discretion upon application and if good cause appears, issue a special permit authorizing the applicant to operate or move a vehicle or combination of vehicles or special mobile equipment of a size or weight of vehicle or load exceeding the maximum specified in this code.

Bridges with a vertical clearance greater than 13 feet 6 inches should not be susceptible to damage by high load hits because the Vehicle Code prohibits vehicles greater than 13 feet 6 inches from traveling on the roadway unless the following two requirements have been met:

1) Vehicles with a height greater than 13 feet 6 inches but less than or equal to 14 feet may travel on State highways if the owner of a vehicle can verify a safe route.
2) For vehicles that exceed 14 feet, a permit must first be obtained from the California Department of Transportation to travel on the State highway system.

State wide there are currently 11 bridges with a vertical clearance less than or equal to 13 feet 6 inches and only 9 are on one of California's mainline highways. The others are on/off ramps. However, over the years there has been a steady flow of High Load Hits to bridge structures with damage ranging from insignificant to severe. Insignificant damage may include minor scrapes on the bridge soffit, which often times goes unreported. Severe damage includes major structural damage resulting in load capacity reductions, bridge closures, costly repairs and/or total bridge replacements.

The Department of Transportation currently has two databases which track high load hit activity. The Office of Truck Services (OTS) began tracking high load hit incidents in 1996. The information contained in this database is data collected from California Highway Patrol (CHP) reports of the specific incidents. To date, this database is showing 130 high loads hit incidents since 1996. The Division of Structure Maintenance and Investigations also has a database, which contains data on high load hit incidents. Since 1996 the data shows approximately 250 high load hit incidents have occurred. The information contained in this database is data collected by the Area Bridge Maintenance Engineers (ABME), which in part might also be information obtained from CHP. It has been a difficult task to determine exactly how many bridges per year, have been hit by over height vehicles because; the perpetrators do not report many of the incidents. This is evident as indications of high load hits are routinely discovered by ABME during biennial bridge investigations. Although, we cannot determine exactly how many high load bridge hits occur annually, we do know they occur regularly.

The proposed system will help in reducing the bridge hits in two ways. On one hand it will provide an alert signal to the driver of the tall load vehicle of impending collision with the structure and on the other hand this system will help CHP in the effective enforcement of the laws concerning the tall load vehicles which in turn will increase the awareness among the commercial vehicle operators.

Objectives of the project

The prime objective of the project was to evaluate products offered by two companies. These companies are CYRA and Bridge-Test.

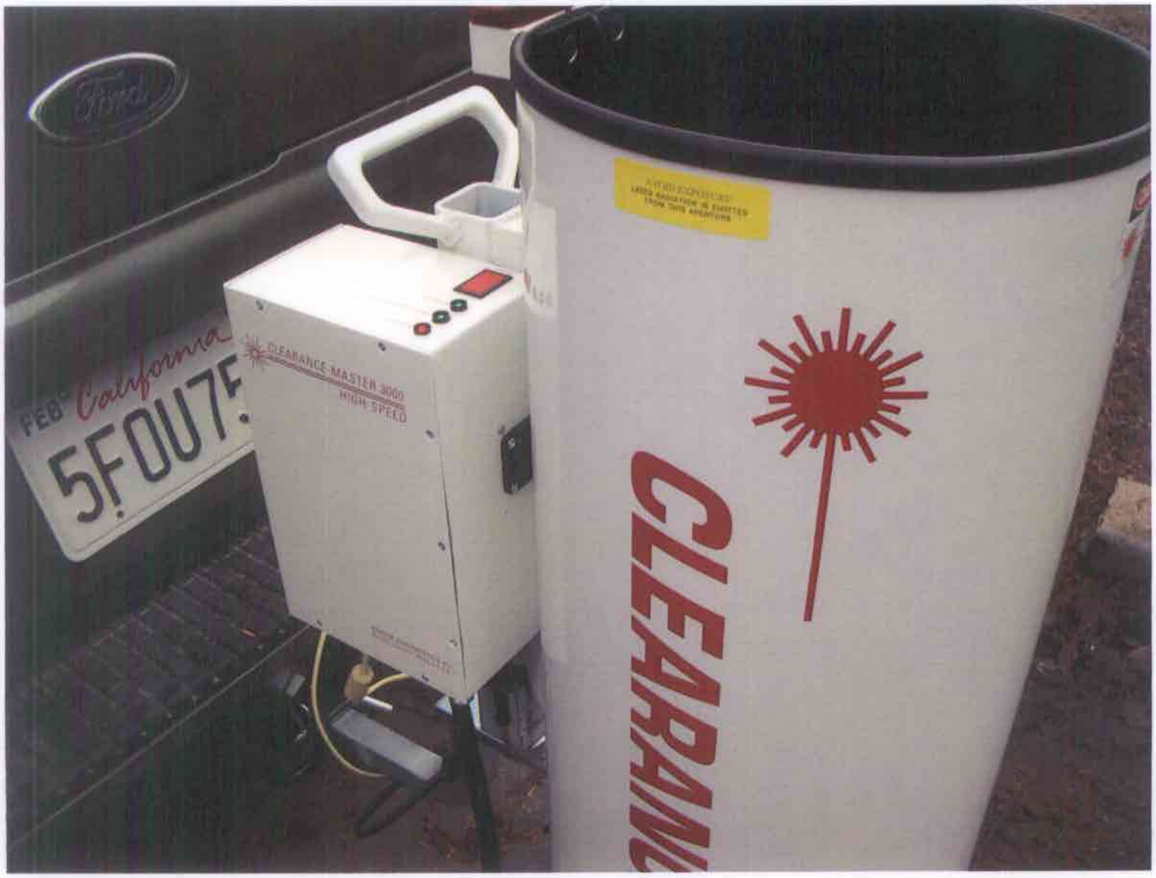
Bridgetest Bridge Master 3000 System Testing

We tested Bridge Master 3000 system on January 10, 2005. Bridge Master 3000 measures bridge heights by shooting a laser upward towards the underside of the bridge structure. This device also shoots an ultrasonic wave downward to measure the distance from the device mounting height to the ground. The on-board computer then adds the two measured distances and compute the clearance from ground to the under side of the bridge.

This device is mounted on the vehicle using a custom Class III hitch mount and continuously records clearance measurements as the vehicle crosses below the structure at highway speeds. Both laser and ultrasonic ranging technologies are utilized, providing an overall accuracy of better than 1/2 inch (13mm). The complete profile of the bottom of the structure is recorded, and the minimum measurement is then extracted and stored. Various mounting options allow the unit to be installed either on the front or rear of the vehicle.

Mounting Hitch Installed on a Standard FORD SUV

Installed Bridge Measuring Device



Bridge Measuring Device Ready for use

The device can also be mounted on the universal bumper mount. The universal bumper mount has been designed for front and rear, driver or passenger side vehicle mounting. Since most inspection vehicles are equipped with a standard Class III (2in) receiver hitch and power hookup, the device can be mounted with ease using the supplied custom trailer hitch. This custom hitch along with different combinations of height shims allow the device to be used with any vehicle outfitted with a Class III receiver hitch. Alternatively, with a few simple modifications to the testing vehicle, the unit can be mounted to the front bumper.

The data from the device is recorded on a standard laptop with USB port. The supplied software stores the data and also provides the lowest point on the structure. The device comes in a carrying case made out of Aluminum and can be carried or shipped to various offices for use.

Device in the carrying case

We found the device to be fairly accurate and we recommend its use for the department to measure the bridge heights.

CYRA Structure Scanning System

The Test

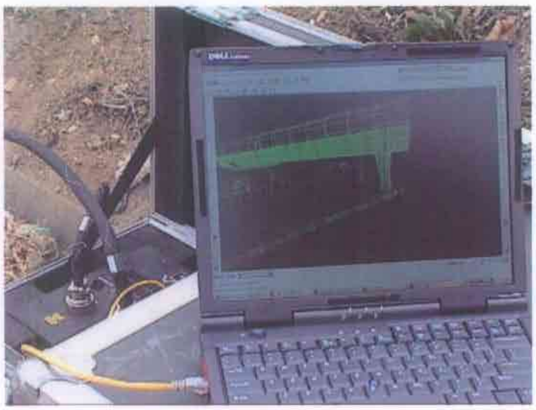
CYRA's sales person, Robert Gardiner, made a presentation at the Office of Research late December 1999. Robert presented some cases where the Cyrax 2400 system was used and produced astonishing results. Based on the facts presented to us, we decided to put the Cyrax 2400 system to the test. We invited Robert to bring the system and scan a structure for us.

Although the cases presented in the presentation were really good, there were several factors that prompted us to request seeing the system in action. We believe that unless the system is put to the test we will not be able to see what the limitations are. Similarly, even though the scanning procedure looks rather simple, we were not sure how long it takes to process the data off-line and to bring the data in usable form. Accuracy and ease of use were the most important factors that we were interested in. The other important factors were battery limitations, number of persons required to carry the operations, transporting the equipment, setup time, time it takes to complete a scan and safety in using the system.

I selected the 51st Street Overcrossing on Highway 50. The bridge number is 24-0315. The location is shown on the map below. There were several factors for the selection of this bridge. This bridge is close to our office. I already took some measurements on vertical clearances on this bridge using the conventional measuring pole. It was easy to cross check the readings I was going to get from the Cyrax 2400 system with the readings I had taken earlier with other means.

We went out on January 04, 2003 to test the Cyrax 2400 system. Before going out, I met with Robert Gardiner and Guy Cuttings from CYRA technologies at our office. We left the office around 10 AM after I explained the safety rules to both of them. Hassan Aboukhadijeh was with me for assistance. We picked up cones from the lab at 59th Street before leaving for the overcrossing.

We parked on the East-bound shoulder on Highway 50. Guy and Robert unpacked the equipment and set the system to scan. The process of setup took about 15 minutes. Guy took the initial picture of the over crossing to check where the scanning head is looking. The scanning range for the scanning head is 40 degrees vertical and 40 degrees horizontal. The scanning head initially provides a still picture taken by the camera mounted on the scanning head. The user can use this picture as reference to set the scanning limits. Due to the size of the over crossing and the distance from which we were scanning it was not possible to scan the whole over crossing in one scan. It took us two separate scans to complete the east side scan of the over crossing. Each scan took about 13 minutes to complete. The pictures below shows the scanning process in progress and the over crossing.



The System

Cyrax 2400 is a three-dimensional (3D) laser scanning system that was developed by CYRA Technologies. Cyrax uses a fast scanning laser system to measure and visualize large structures like bridges, buildings etc. The information is then stored in a computer using integrated software in a "point-cloud" form. Each point is stored in form of a point-cloud and carries 3D information in form of (X,Y,Z) coordinates. This point cloud can be viewed in a 3D form. Point-cloud can be rotated and users can fly-around the scanned structure. The point-cloud represent a highly detailed, instantaneous three-dimensional, survey-grade "virtual model" of an existing site or structure

The Cyrax 2400 consists of scanning head, power supply unit and a laptop computer running the integrated software. Scanning head is connected to power supply unit via two cables. These cables not only power up the scanning head but they also provide the information exchange between laser head and power supply. The laptop is connected to the power supply from where it gets the information coming from the scanning head.

The scanning head (shown above) sits on top of a heavy-duty tripod, as it weighs about 65 pounds. The laser used is eye safe and conforms to class II standards of laser safety code (CFR 1040).

The power supply unit (shown below) weighs about 47 pounds excluding the carrying case. Please note that the power supply unit is located inside the carrying case. The power supply unit can use 90-240 Volts in AC mode or 24 Volts in DC mode. Power consumption is approximately 125 Watts. With fully charged batteries the scanner can scan for about four hours. The yellow cable connects the power supply to the laptop computer. This cable is for data exchange only and not to power up the laptop.

The third part is the laptop and the software. The proprietary software helps the user selects the limits of scan by first providing an image. A camera that is also mounted on the scanning head generates this image. The user then selects the area on the image that needs to be scanned. Once the limits are set then these limits are passed on to the scanning head computer that in turn starts the scanning process. The data is passed to the laptop computer as the object is scanned. The user can stores the point-cloud once the scanning process is complete. The yellow cable that connects the laptop computer to the power supply uses a 10baseT format. The laptop is equipped with a PCMCIA type II card supporting with 10base T connector.

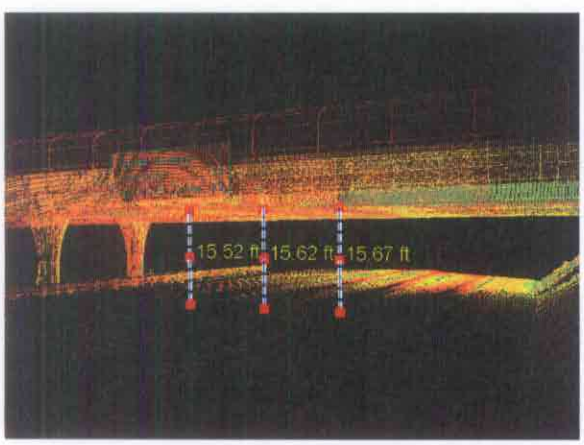
Observations

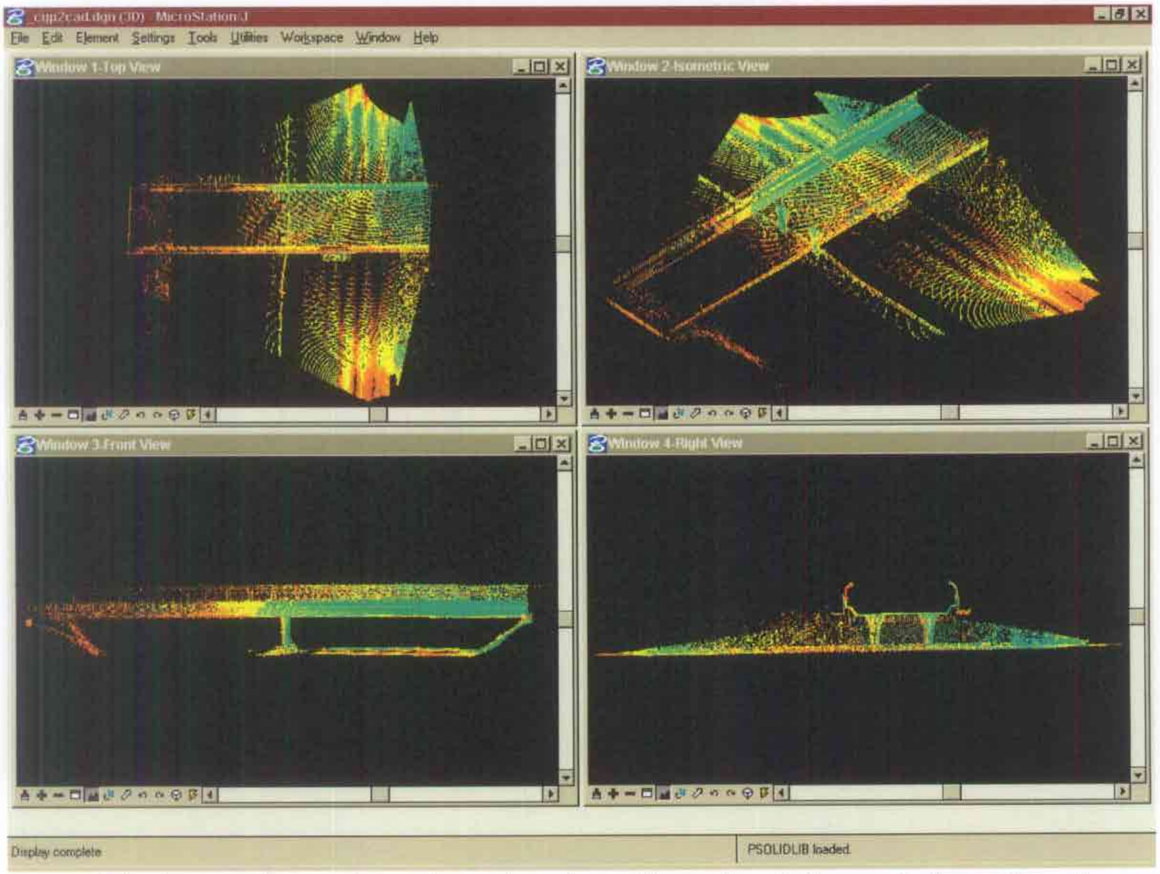
Two personnel are required to operate the Cyrax 2400 scanning system. This is due to the weight and the delicate nature of the scanning head. Scanning head consists of a set of rotating mirrors that makes it rather delicate. The equipment is carried in heavy-duty hard cases that can be seen in the pictures above. The removal of the equipment from the vehicle and setup needs two personnel.

The scanning process is simple, once the system is in place. The operator captures the image from the camera mounted on the scanning head. This image gives the operator an idea where he is looking at and whether the image shows the area on interest or not. The picture below shows the image on the laptop computer.

The operator then selects the area that needs to be scanned on the image using the mouse. Once the area is selected the operator gives the command to start scan. As the scanning starts the scanned data is shown on the laptop computer monitor. Each scan takes about 13 to 15 minutes to complete based on how many points per line needs to be scanned. In our case we were scanning with a resolution of 800 by 800 points. The Cyrax 2400 has the capability of going all the way up to 1000 by 1000 points.

It took us two scans to complete the east side of the over crossing and three scans to complete the west side of the over crossing. The reason it took three scans to complete the west side of the over crossing is due to the distance from which we were scanning. It was possible to move a little bit further and complete the scan of the over crossing in just two scans. The reason I decided against was due to the fact that I wanted to see how well the five separate files can be integrated in to one three dimensional database. It took three hours to integrate the five different scan files to make a complete model of the bridge. The readings shown below can be taken without the complete integration of all the individual scanned files. Although the Engineer from CYRA did not convert the complete file into Microstation format, he mentioned that it would take about 30 to 40 hours for conversion. Some of the scanned images (east bound) are included here.

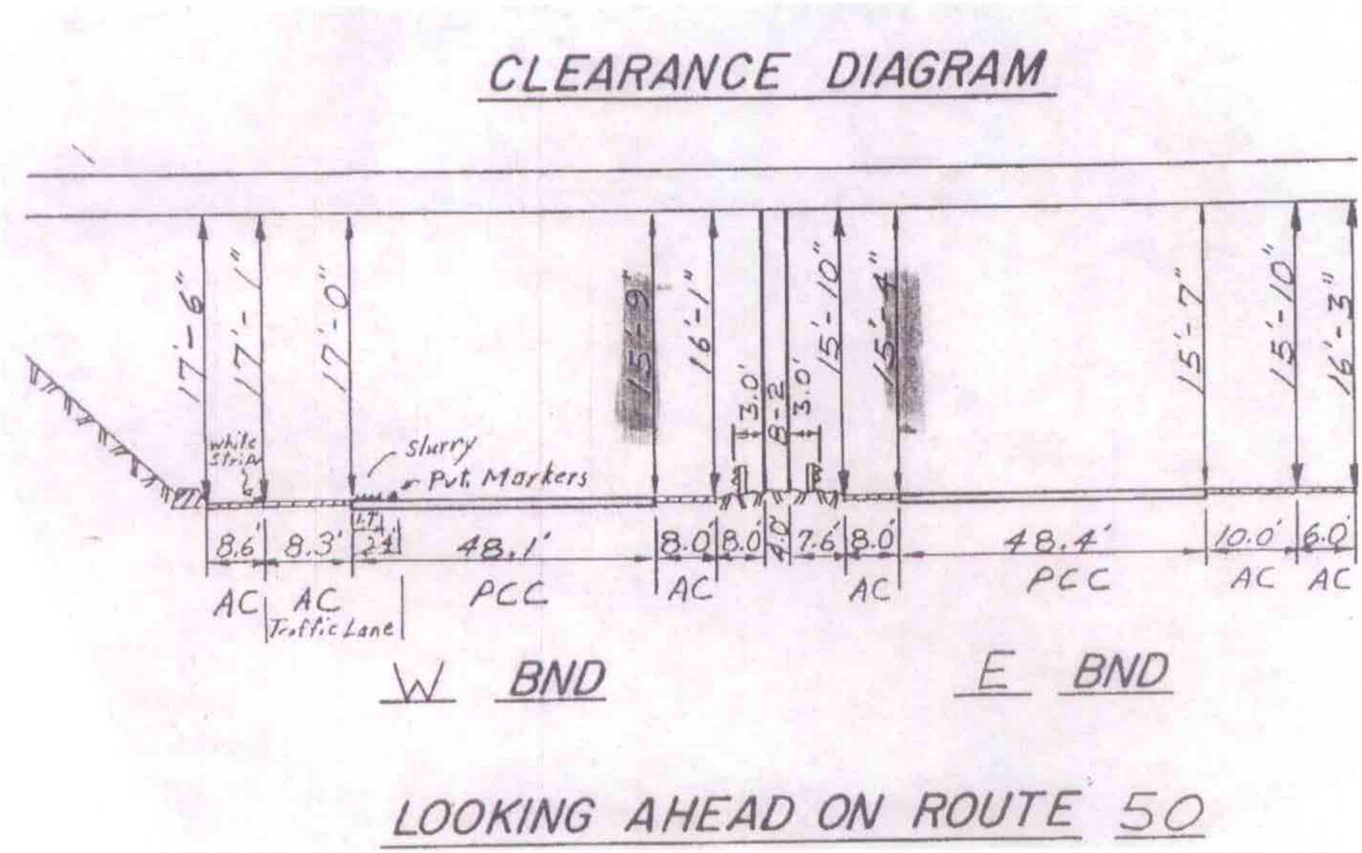




The image shown above (complete three-dimensional diagram) shows how the point cloud looks in Microstation.

The Cyrax 2400 is safe to use as it uses eye-safe laser. The problem comes when scanning a bridge while parked on the shoulder. Some protection is required to protect the personnel and equipment from being hit from behind.

Accuracy is good. After comparing the readings from Cyrax 2400 and the vertical clearance diagram from Permits branch, the differences are minor. The vertical clearance we got from the Cyrax 2400 conforms to the vertical clearance diagram we got from permits branch. The minor differences (within an inch) are due to the face that the readings are taken at different points. Below is a scanned drawing of vertical clearance diagram from permits branch of the 51st over crossing.



Conclusions

Bridge Master 3000
We believe the accuracy for this device is good and a quick installation and data recording makes it a viable and good choice for the department. We recommend this device use for the department.

CYRA Structure Scanning System
Cyrax 2400 has value for scanning existing structures for accurate as-builts. It can also be used to measure structures where a taking a measurement is impossible, for example measuring a bridge from abutment to abutment. It is however difficult to justify this system solely for the purpose of measuring vertical clearances of existing bridges mainly because it takes considerable amount of time to get that data as opposed to some of the hand held devices currently used by Caltrans, also the cost is around $170,000, without the cost of a laptop, making it a rather expensive system.