GT-8K: World's First Infrastructure Inspection Vehicle using 8K Video Technology

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1. Introduction

So far, 8K technology has developed mainly for broadcasting. NHK Science and Technology Research Laboratories has been developing 8K under the name of Super Hi-Vision since 2004 and began 8K broadcasting in 2018. During development, several large scale specialized devices were used for filming, but for roughly 15 years, 8K equipment has become more compact, 8K TVs have appeared on the market, 8K video compression technology has advanced, and products such as 8K processing workstations have entered the market.

Through this process, the characteristics of 8K have also been widely researched, and applications in industry are highly anticipated. One characteristic of 8K is that it can capture high-definition state over a wide area. If an unexpected outcome is perceived from the overall image, the overall features can be analyzed on a single image rather than attempting to join images from multiple cameras. It is hoped that this will show the benefits of 8K in industry. To apply a new technology such as 8K in industry requires the desired objective to be achieved, but also that the technology is both practical and economical.

ASTRODESIGN has put effort into developing devices for 8K broadcasting and has commercialized successive products including cameras, signal processing equipment, recorders and displays. Here we describe how we provided comprehensive leading-edge technology, when it was needed, during completion of the GT-8K, the world's first 8K infrastructure inspection car. We have conducted repeated trials since development began, and now understand the effects of using 8K technology for infrastructure inspection, so we are now ready to apply the technology. Here, we describe the development process, show operation and results from the inspection system, and results achieved in light of issues with current infrastructure inspection practices.

2. Evolution of 8K equipment

ASTRODESIGN has worked on developing products since the beginning of Super Hi-Vision development, and been broadly involved in 8K products. As FPGAs have advanced, they became a technology for processing 8K efficiently. They have been a high quality signal processing technology for broadcasting, contributing to advancement of devices such as cameras. They are the eye of the system, the entryway for images, and an essential component when considering industrial applications of 8K. Earlier 8K cameras were large systems requiring much power, but their size and power consumption has been reduced, without decrease in performance. These advances have greatly reduced the hurdles to using 8K cameras in industry applications.

Currently, ASTRODESIGN has a lineup of two cameras for industrial use, with model numbers AB-4815 and AB-4830/AC-4829.

Both models can output 8K video (12G-SDI×4 channels) in real time, to use the characteristics of 8K video. The AB-4815 is a compact camera with the main unit measuring 148 mm × 150 mm × 241 mm, which outputs image-processed video and consumes only 90 W of power. The other model, the AB-4830/AC-4829, is separated into a camera head and a video processing unit. The camera head is more compact, measuring only 65 mm ×65 mm × 85 mm and weighing only 340 g. Including the AC-4829 signal processing unit, it only consumes 80 W of power. These compact designs expand the range of possible non-broadcasting applications.

Use of 8K video for industrial applications requires capture as well as storage of the video and processing with CPU/GPU. ASTRODESIGN has developed a hardware-based 8K recorder, but we also developed a workstation able to receive the video data to create a more flexible capture system. The AW-8800 workstation is able to receive 8K video from up to four camera systems. For such a case, the system would be implemented with four capture boards capable of transmitting and receiving

■ **Figure 1: 8K camera (left: AB-4815, right: AB-4830/AC-4829)**

■ **Table 1: AB-4815 specifications**

Item	Specifications
Image sensor	Super 35 mm CMOS image sensor
Effective pixels	Approx. 33 million
Lens mount	PL mount
Frame frequencies	59.94 Hz, 60 Hz, 50 Hz, 30 Hz, 29 Hz, 25 Hz, 24 Hz
External dimensions	148 (W)×150 (H)×241 (D) mm
Weight	3.5 kg

■ Table 2: AB-4830/AC-4829 specifications

Item	Specifications
Image sensor	Super 35 mm CMOS image sensor
Effective pixels	Approx. 33 million
Lens mount	Micro Four Thirds mount
Frame frequencies	59.94 Hz, 60 Hz, 50 Hz
External dimensions	Camera head: 65 (W)×65 (H)×88.5 (D) mm CCU: 210 (W)×133 (H)×370 (D) mm
Weight	Camera head: 340 g CCU: 5 kg

four 12G-SDI channels installed in five-lane PCIe slots. The workstation is also equipped with 16 U.2 NVMe SSDs in a RAID configuration. The system can also be implemented with 8 GB DDR4 DIMM in 24 slots, so the system can record even uncompressed high-bit-rate video data. The CPU has 56 cores, so that workstation-based systems can be built for high-performance and specialized applications, able to process 8K in real-time.

The 8K infrastructure inspection system described here is a simple configuration including four 8K cameras (AB-4815) and an AW-8800 workstation.

■ Figure 2: AW-8800 TAMAZONE workstation

■ Table 3: AW-8800 specifications

Item	Specifications
CPU	Intel® Xeon® processor×2 (56-core)
Memory	DDR4-2666 8 GB×24
Drive	2.5” U.2 NVMe SSDx×16
GPU	NVIDIA® Quadro® P4000
PCIe slots	PCIe Gen3×16 4-Lane PCIe Gen3×4 (DMI) 1-Lane
Chassis	5U Chassis, 28.7” (L) ×18.0” (H) ×8.54” (W)

3. GT-8K: World’s first infrastructure inspection car

During the years of rapid economic growth in Japan, large amounts of social infrastructure were built, including roads, tunnels, and railways. As this infrastructure deteriorates, managing maintenance is becoming more important, while at the same time, a shortage of inspection personnel and increasing inspection costs are becoming major issues. The Ministry of Land, Infrastructure and Transport has designated infrastructure facilities that were built 50 years or more in the past as deteriorated facilities, and is working on policy to replace inspection, which has basically involved close visual inspection, with technology.

On June 3, 2020, Aero Asahi Corporation and ASTRODESIGN announced completion of joint development of GT-8K, a new measurement vehicle equipped with 8K video technology to advance and increase performance in maintenance of various infrastructure such as roads, railways and airports. It is a vehicle-mounted Mobile Mapping System (MMS) and is able to record 8K video while travelling at highway speeds, linking it with positioning data to collect accurate data at high speed. The Aero Asahi Corp. mobile measurement vehicle technology combined with ASTRODESIGN’s high-quality video technology creates a highly accurate and practical measurement system.

Since 2019, we have conducted repeated trials inspecting tunnels, demonstrating that we achieved our goal of detecting cracks on the order of 0.1 mm to complete the photographic system. Till now, we have been operating the GT-8K and integrating the crack detection system with point cloud data. Using the results, we have implemented industry applications of 8K, delivering measurement services and the measurement data as a commercial product.

■ Figure 3: GT-8K (left) and GT-8K in operation (right)

4. Measurement system configuration

GT-8K consists of four 8K cameras, a video collection workstation, high-output illumination and a laser scanner, all mounted on a vehicle.

The image capture component has 8K cameras with fixed-focus lenses, which send video signals to the components in the vehicle. The cameras also have high-powered lighting on both sides to ensure that the tunnel walls are adequately illuminated. The laser scanner component is equipped with a Global Navigation Satellite System (GNSS) antenna, an Inertial Measurement Unit (IMU) and a laser scanner. The GNSS is not able to receive radio signals inside a tunnel, so the IMU positioning measurements enable the system to record accurate positioning data as the vehicle moves, even while in a tunnel. Based on this positioning data, point cloud data is generated using the laser scanner. Overall control of the system and data collection is done by a PC in the vehicle, and data collection can be monitored in real time on a terminal in the vehicle as it moves. All of this equipment is driven by a power supply installed under the cabinet. The simplified system configuration enables the entire system to be installed on a single vehicle.

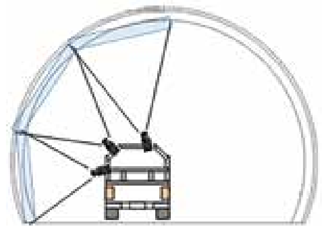
The laser scanner is able to acquire range data for one million points per second. By combining this point cloud data with the 8K video, an expanded image of the inside of the tunnel is created with both location and image information.

The video and point cloud data are synchronized during capture using a video synchronization signal (30 Hz TTL pulse). The cameras output 30 Hz 8K video and the workstation is equipped with up to four 12G-SDI capture cards. The PC receives uncompressed video, which is transferred to main memory, and then written sequentially to the SSDs. The input video data rate is 96 Gbps, and the application is optimized to ensure that no data is lost. To enable monitoring of the measurement status, the image data in the SSDs is also processed to display it on a terminal as it is recorded.

Three or four cameras are used for measurement of the surface of tunnel walls. The number of cameras and lenses are selected beforehand based on the tunnel shape, and the position and orientation of the cameras on the cabinet and the path of the vehicle are adjusted through prior simulation and at the site.

Figure 4: GT-8K configuration

Figure 6: Capturing tunnel wall surfaces

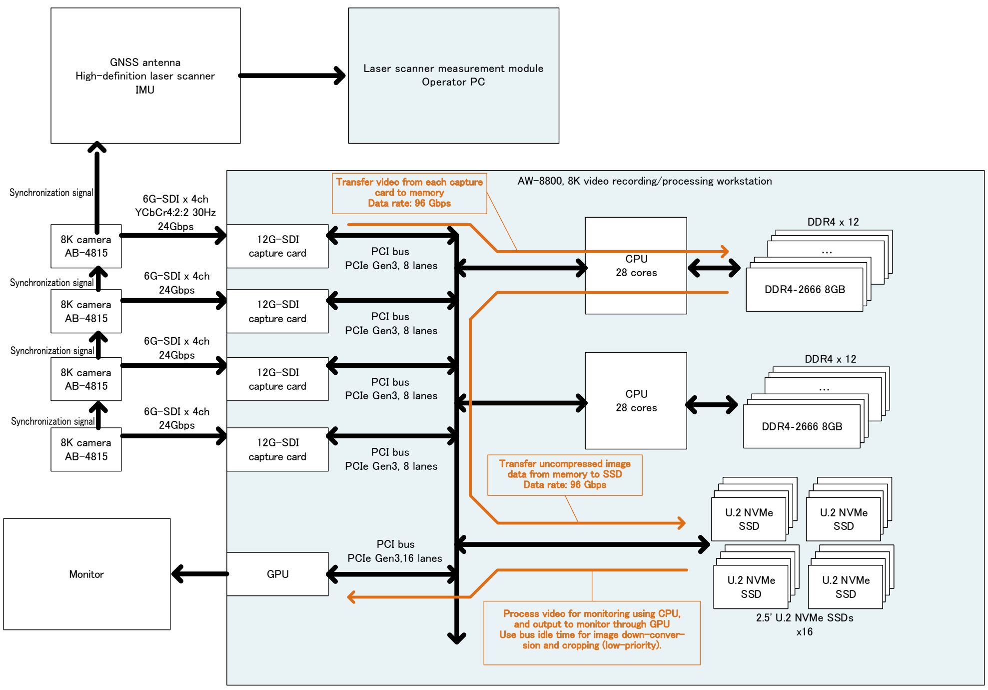


Data collection is then performed after tuning the lens focus and lighting conditions. To utilize the horizontal resolution of the 8K video, the cameras are tilted by 90° facing the wall surface. To capture an entire tunnel with inner circumference of 15 m, three cameras are used to capture the left-hand surface, and the vehicle drives down the opposite late to capture the other half.

In this case, a single camera captures an area of 2.5 m × 1.4 m, and each pixel represents an area of approximately 0.3 mm × 0.3 mm. We have targeted this 0.3 mm size when measuring cracks, but there is a high contrast ratio between cracked areas (which appear black) and the tunnel walls, so we are able to use this difference in contrast ratio to measure cracks that are smaller than the pixel size. In practical tests, we have been able to discriminate cracks down to approximately 0.15 mm.

To capture from the vehicle while it is moving requires suppression of motion blur. When capturing at 30 Hz and travelling at 60 km/h, the vehicle travels roughly 550 mm during a single frame. To suppress motion blur due to this motion, the camera shutter speed must be increased. Using a shutter speed of

Figure 5: GT-8K system schematic diagram



1/10000 s, image blur can be reduced to approximately 1.5 mm. When conducting data measurements, target capture conditions must be verified beforehand, and also adjusted at the site. The 8K cameras and workstation provide advantages for achieving this in that the system is simplified and has functions for real-time tuning at the site.

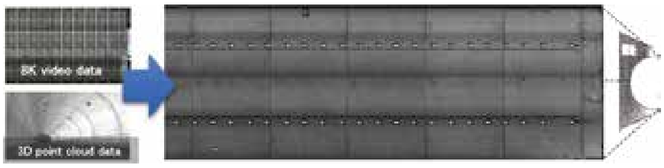
An expanded image of the tunnel is generated by combining the 8K video with the point cloud data obtained when collecting the data. The images are combined by projecting a mosaic of the images onto a 3D projection surface generated from the laser data using the position and orientation of the camera. The complete expanded image is further processed to provide a record of the position and shape of any cracks. Besides cracks, areas with water stains, and where markings have been added manually in the past are also isolated comparatively.

The expanded view image can be analyzed automatically using image processing and can also be inspected visually by an inspector at a later date. The data is also archived, so any changes detected in periodic inspections can also be used for forecasting future changes.

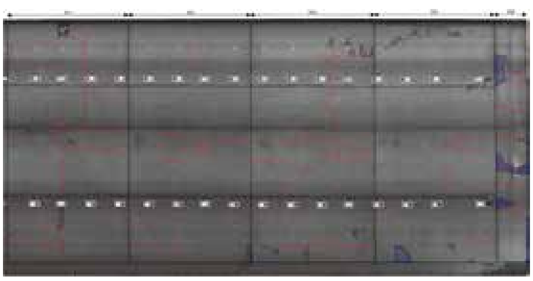
5. Benefits of the 8K infrastructure inspection vehicle

Creating this expanded view from the video captured using the 8K infrastructure inspection vehicle enables automation of inspections, reduction in required personnel, increased accuracy, and greater stability of inspection quality. Compared with

■ **Figure 7: Tunnel expanded view**

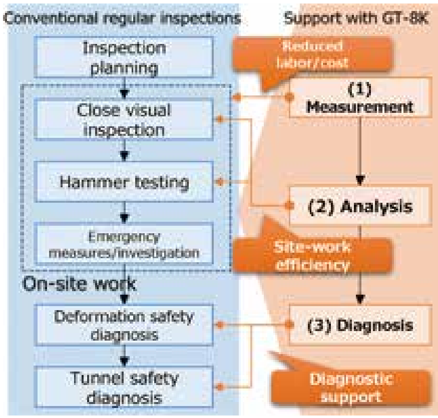


■ **Figure 8: Image processing results**



■ **Figure 9: Image analysis**

■ **Figure 10: GT-8K inspection support**



conventional periodic inspections, the labor and costs of the close visual inspections, hammer testing and other tests required in the past are reduced and on-site work is more efficient. The system also supports diagnosis of tunnel shape and soundness, improving the quality of the diagnostics that can be done.

Use of 8K cameras in the inspection system reduces the number of cameras needed and reduces the preparation and tuning time required. It can also be expected to help reduce difficulties and errors, and to simplify monitoring during image capture. Image captured with the video cameras are consecutive in time and with images taken from other viewpoints, they can complement each other to enhance the inspection. Even for images that are difficult to discern due to the light and shadows of a structure, other images can be used for the inspection, increasing reliability and utility of the inspection. In particular, the system is designed to maximize performance of the 8K cameras, so the expanded view of the tunnel retains the color and texture of the images. This makes the inspection similar to a visual inspection, so that inspectors can use their experience gained in the past.

6. Conclusion

The increasing amount of deteriorating infrastructure is becoming an urgent issue, and we have tested effective use of 8K video technology for work inspecting such infrastructure. Digitalization of inspections promotes efficiency, and can also increase reliability, so we can expect it to be used in an increasing range of scenarios in the future. The characteristics and potential of 8K are extremely well suited to the field of infrastructure inspection, and we expect that even more successes and research results will appear in the future.

In this case, we examined roadways and tunnels, but there are also other infrastructure areas such as bridges, railways, water supply and drains, gas and electricity. We will continue to refine our technologies so that 8K can be used to increase safety and efficiency with respect to the huge amounts of infrastructure in these areas as well.