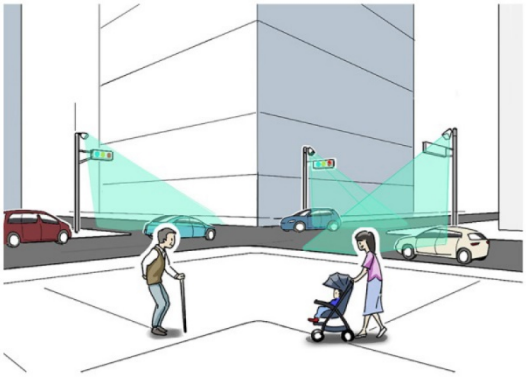
Building Safe and Secure Mobility Infrastructure to Support CASE Society



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*Mitsubishi Heavy Industries, Ltd. (MHI) Group will link its Intelligent Transport Systems (ITS), mechanical parking systems, and environmental testing systems, which have been worked on separately in the past, and utilize modeling and simulation (M&S) technology developed in the plant system and other fields. The aim is to realize the establishment of safe and secure infrastructure by enabling the use of AI technology with a small amount of data for the road transport sector, which is facing a major transformation due to the advancement of CASE[*1]. This report introduces each of these efforts.*

*1 Stands for Connected, Autonomous, Shared, and Electric, which are technology trends in the automotive industry to build safe and convenient next-generation mobility services.

1. Introduction

The automotive field is facing a period of major transformation due to the advancement of CASE, but the values of improving safety, efficiency and reducing environmental impact remain unchanged. These values are also consistent with the vision of MHI Group. MHI Group has long been involved in products such as testing systems, ITS, and mechanical parking systems that support the automotive sector. By developing these technologies and developing the infrastructure to support CASE, MHI Group aims to realize a safe and secure society and promote decarbonization, energy saving and manpower saving.

The infrastructure for supporting the advancement of CASE that MHI Group is working on consists of three major items. **Figure 1** shows the overall picture of the efforts.

The first is indoor integrated environmental testing facility capable of high-precision testing to support the development of increasingly complex automated vehicles. The second is a safety monitoring service that improves safety by providing out-of-sight forward road information to support the operation of automated vehicles. The third is a “Smart Stockyard” equipped with automatic valet parking, electric vehicle charging and discharging, and enhanced automatic refueling and maintenance functions, to be used as a base facility to support the development of CASE and MaaS[*2] society.

The following chapters introduce the details of each of the efforts.

*2 MaaS: Stands for Mobility as a Service. A new concept of mobility that seamlessly links all modes of mobility (transportation) other than personal cars as a single service by utilizing ICT to form transportation into a cloud.

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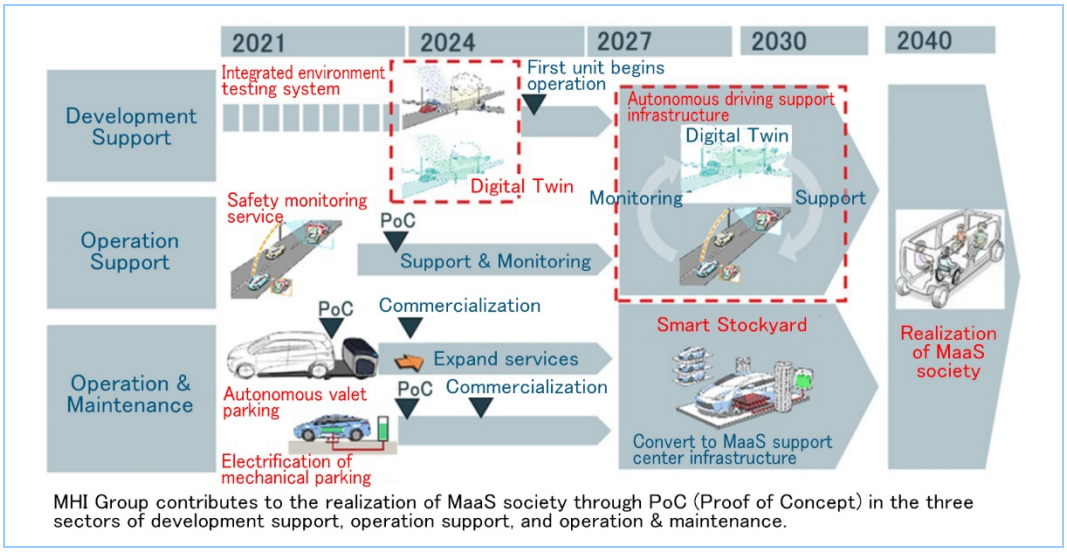

Figure 1 Building infrastructure to support the advancement of CASE, which MHI Group is working on

2. Integrated environmental testing facility

2.1 What is the integrated environmental testing facility?

Automated vehicles are under vigorous development worldwide. It is expected that their capabilities will improve dramatically and that they will become more widely used in the future. On the other hand, to guarantee their safety and security, it is necessary to verify that sensors and systems function properly in the diverse natural environments that automated vehicles face, and it is anticipated that the need for all-environmental testing facility will increase in the future. MHI Group is developing an indoor integrated environmental testing facility that can generate any combination of natural environments (snow, fog, rain, light, etc.) and driving conditions to test automated vehicles with high precision, and a system that enables comprehensive verification under virtual environments, in collaboration with Applus+ IDIADA, a multinational company based in Spain that performs engineering, testing, and homologation for the automotive industry. **Figure 2** shows the concept of the automated vehicle testing and verification system and integrated environmental testing facility. This aims to help automotive manufacturers and sensor manufacturers shorten the development period of automated vehicles and reduce development costs by stably creating natural environments and driving conditions, such as fog and rain, which cannot be reproduced in public road tests. Furthermore, we intend to contribute to the standardization of safety performance verification methods by feeding back the know-how and practices obtained from the integrated environmental testing facility to the international standards and homologation for automated driving.

*1 SILS: Software-In-the-Loop-Simulation
*2 HILS: Hardware-In-the-Loop-Simulation

Digital Twin technology enables the mutual complement of reproducible all-environmental testing and vast simulations in the virtual testing.

Figure 2 Concept of testing and verification system of advanced automated vehicles and integrated environment testing facility

2.2 Technology for supporting integrated environmental testing facility

The integrated environmental testing facility that reproduces any natural environment indoors requires cross-cutting technologies: the first is radar wave reflection and scattering control technology to suppress and control the effects of the indoor environment that makes testing of radar sensors installed in automated vehicles difficult due to increased reflection and scattering; the second is environmental testing technology to control the temperature and humidity throughout the test facility to reproduce snow, fog, etc.; and the third is system integration technology to combine these technologies into an automotive testing facility.

For the development, the technologies of three companies in the MHI Group will be brought together, comprising the radar wave reflection and scattering control technology of Mitsubishi Heavy Industries, Ltd., the environmental testing technology for air-conditioning and refrigeration equipment of Mitsubishi Heavy Industries Air-Conditioning and Refrigeration, Ltd., and the system integration technology for automotive testing facility of Mitsubishi Heavy Industries Machinery Systems, Ltd., to promote the construction of the testing environment required for automated vehicles.

3. Safety monitoring service

3.1 What is the safety monitoring service?

Recently, tests for the practical application of automated vehicles have been conducted in various road environments. Given that, one of possible scenarios would be that safety to be ensured not only by relying on the sensors and functions of the vehicle itself, but also by cooperating with the infrastructure have emerged. For example, on highways, the visibility for vehicle's on-board sensors may not be sufficient to smoothly change lanes, decelerate, or take other safety measures in response to lane restrictions due to accidents, constructions, falling objects, sudden weather changes, traffic congestions and etc. It is considered essential to provide out-of-sight forward road information from the roadside infrastructure for smooth and safe driving in such cases. MHI Group aims to contribute to the establishment of safe and convenient next-generation mobility society by delivering those out-of-sight forward road information to automated vehicles using vehicle-to-infrastructure communications. **Figure 3** shows the concept of the safety monitoring service.

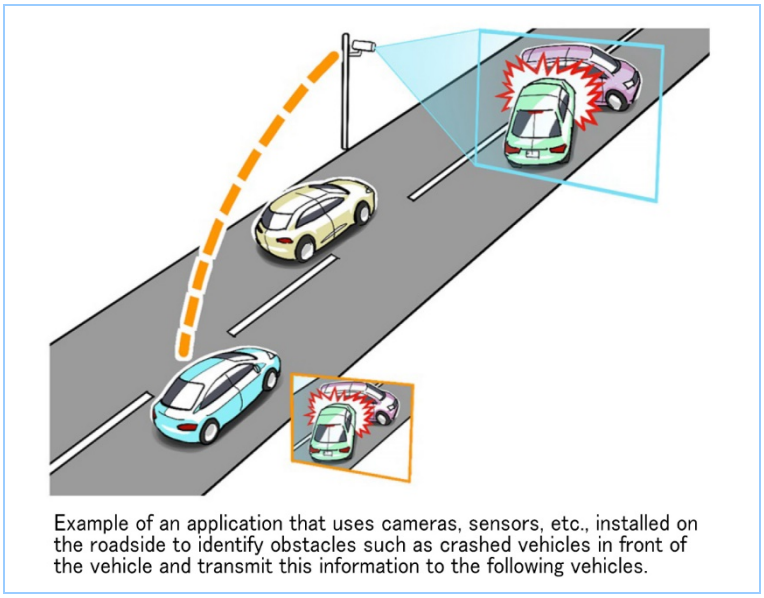

Figure 3 Concept of safety monitoring service

3.2 Technology for supporting safety monitoring service

MHI Group has a proven record of solutions for road charging and road control, including toll collection on expressways and congestion charging (road pricing) in urban areas. Mitsubishi Heavy Industries Machinery Systems, Ltd. has provided these technologies for about 60 years, and has accumulated technical expertise in wireless communications and image sensing in the road environment. In addition, Mitsubishi Heavy Industries Engineering, Ltd. has established a railroad system in which ground systems cooperate with on-railroad vehicle to ensure safety and has the expertise to analyze and evaluate the safety of the system. MHI Group aims to establish a safety monitoring service by utilizing these technologies and expertise.

Mitsubishi Heavy Industries Machinery Systems, Ltd., jointly with Spectee Inc., applied to a public call for a demonstration test of safety monitoring service by Central Nippon Expressway Company Limited (NEXCO Central Japan) in February 2022, and the application was adopted. This verification test is scheduled to be conducted on an about four-kilometer section located between Shin-Hadano Interchange to Shin-Gotemba Interchange, an unused part of Shin-Tomei Expressway, in Shizuoka Prefecture, and preparations are underway to conduct the test in fiscal 2023. The test will consist of three parts: (1) "Provision of road obstacle information to following vehicles", (2) "Provision of optimal speed information, etc., according to road surface conditions and driving environment", and (3) "Support of by-destination following travel". (1) and (2) are expected to contribute for a reliable automated driving, by delivering out-of-sight forward road information that cannot be detected by the onboard sensors of the vehicle using vehicle-to-infrastructure communications. (3) provides information to autonomous vehicles to

activate or cancel traveling in platoon and following each other. The platooning of autonomous vehicles is expected to realize energy-saving driving by reducing air resistance, etc.

4. Smart stockyard

4.1 What is the smart stockyard?

Parking spaces are an important transportation infrastructure indispensable to society, providing convenience to users of commercial facilities and office buildings. MHI Group has been providing a variety of "eco-friendly mechanical parking systems" that reduce the time required for entry and exit, reduce noise, further improve safety, and enhance ease of use. MHI Group is seeking to evolve the parking systems into "smart stockyards" with enhanced automatic valet parking, electric vehicle charging and discharging, and automatic refueling and maintenance functions, as base facilities supporting the coming MaaS society through the advancement of CASE.

An automated valet parking system uses automated driving technology to provide unattended parking at commercial facilities, large complexes, shopping malls, airports, etc. MHI Group is working with Stanley Robotics (SR), a French venture company, to develop an automated valet parking system using an automatic guided vehicle (AGV), car carrying robot named "Stan". **Figure 4** shows the concept of the automated valet parking system. The introduction of this AGV robot will free users from the hassle of searching a vacant parking space in a large parking lot and walking to a distant parking lot while carrying large items after shopping as an example. Furthermore, this parking system enables users to load their luggage into their cars in a large space, making the entire series of activities from arrival to departure stress-free. In addition, this parking system can increase the number of vehicles that can be accommodated in the same lot area by up to 50% compared to conventional parking lots by changing the arrangement, enabling parking lot owners to make more efficient use of the limited area. The AGV robots are battery-powered, contributing to the reduction of CO_2 emissions generated in parking lots.

Figure 4 Concept of automated valet parking system

Automated vehicle transport and storage services can be applied to transport finished vehicles from automotive plants as well. **Figure 5** shows the concept of finished vehicle transportation. This would enable 24 hours and 365 days operation in automotive plants, ports, motor pools, etc., solving the problem of a shortage of skilled drivers, and realize low-cost and safe transportation at the same time.

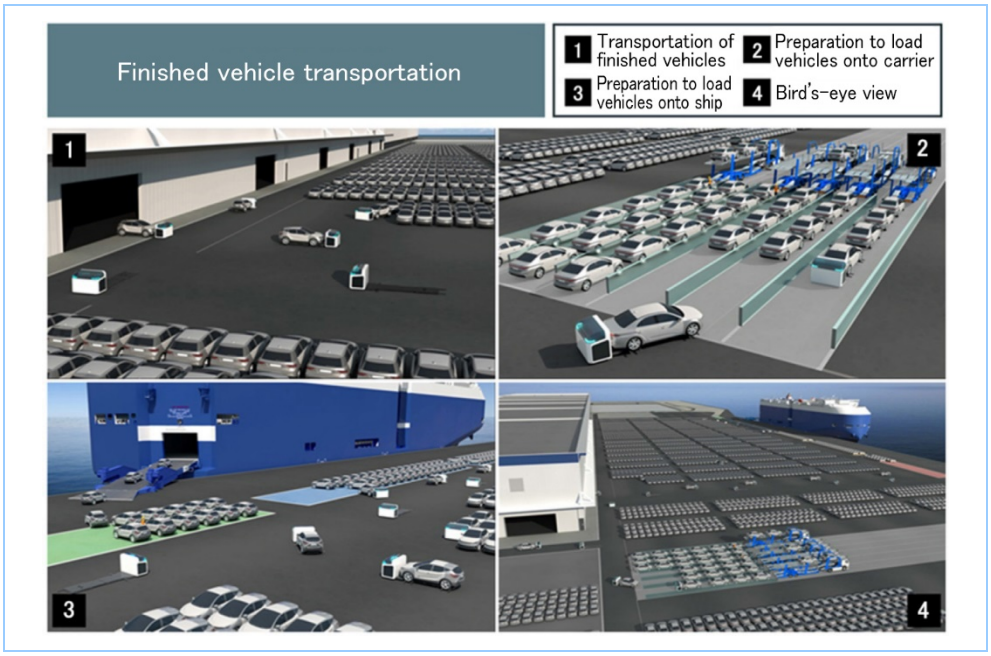

Figure 5 Concept of finished vehicle transportation

For the electrification of parking lots in response to the increase of electric vehicles, MHI Group is proposing electrification solutions not only limited to installation of charging and discharging facility but also, control of the charging sequence, keeping the required electric power within the power receiving capacity of the facility, and charge/discharge management to optimize power costs.

In the future, MHI Group aims to apply energy management technology developed over many years in power generation plants and combine the batteries of electric vehicles accumulated in parking facilities, photovoltaic cell and stationary storage batteries to supply electric power adjusted for each facility. MHI Group is seeking to operate these facilities as an integrated demand response or virtual power plant to contribute to the stabilization of the regional power grid.

4.2 Technology for supporting smart stockyard

In the field of automated valet parking systems, MHI Group is collaborating with Stanley Robotics (SR), a French venture company that has pioneered the world's first automated valet parking system using AGV robots. By combining the AGV robots provided by SR with the mechanical parking systems, traffic flow control technologies and unmanned system monitoring and management technologies developed, MHI Group has capability to provide services that meet a wide variety of customer needs. MHI Group hopes to create unprecedented new value in advance of the full-scale spread of automated driving (**Figure 6**).

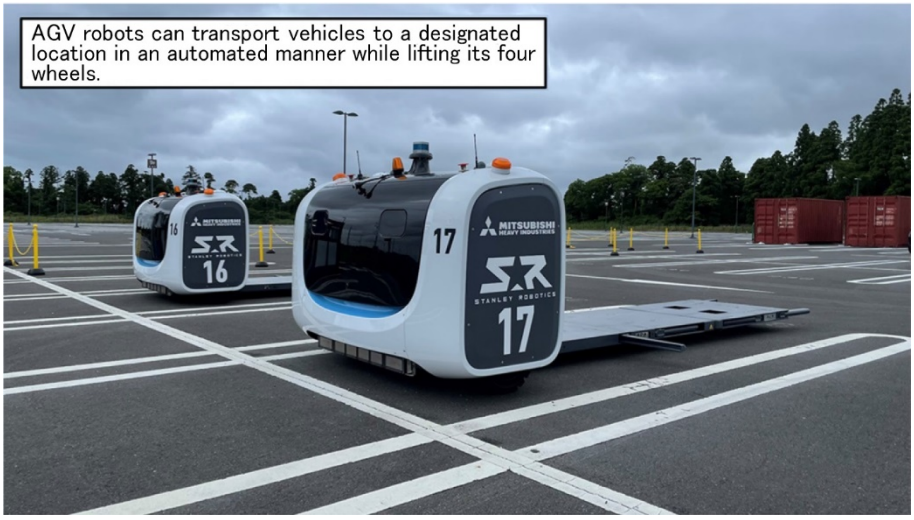

Figure 6 Stanley Robotics AGV car carrying robot "Stan"

MHI Group has conducted a demonstration test of the automated valet parking system using AGV robots for the first time at a commercial facility in Japan in June 2022. The aim is to develop a business of automated valet parking system in Japan. With the cooperation of the Mitsubishi Estate Co., Ltd. Group, MHI Group conducted a demonstration test of automated vehicle transport with AGV robots in a form similar to a real environment at the parking lot of the outlet mall "Shisui Premium Outlets" (Inbagun, Chiba Prefecture, Japan) developed and operated by Mitsubishi Estate-Simon Co., Ltd., to verify the performance of the transport, and evaluated the level of user satisfaction. The system was well received by users with comments such as "it was convenient because all I had to do was just to leave my car in the berth", "Great experience that I didn't have to park in a tight space", etc. Going forward, MHI Group will continue to make improvements to the mechanism and operation based on customer feedback from this demonstration test and provide automated valet parking services using AGV robots to commercial facilities, large complexes, theme parks, airports and other parking facilities, thereby contributing to the realization of a safe, comfortable and sustainable society.

5. Conclusion

This report introduced MHI Group's efforts to build infrastructure to support the advancement of CASE, including integrated environmental testing facility, safety monitoring services, and “Smart Stockyards”. MHI Group will continue to contribute to the realization of a safer and more secure society by bringing together its technologies to promote decarbonization, energy conservation and labor savings.