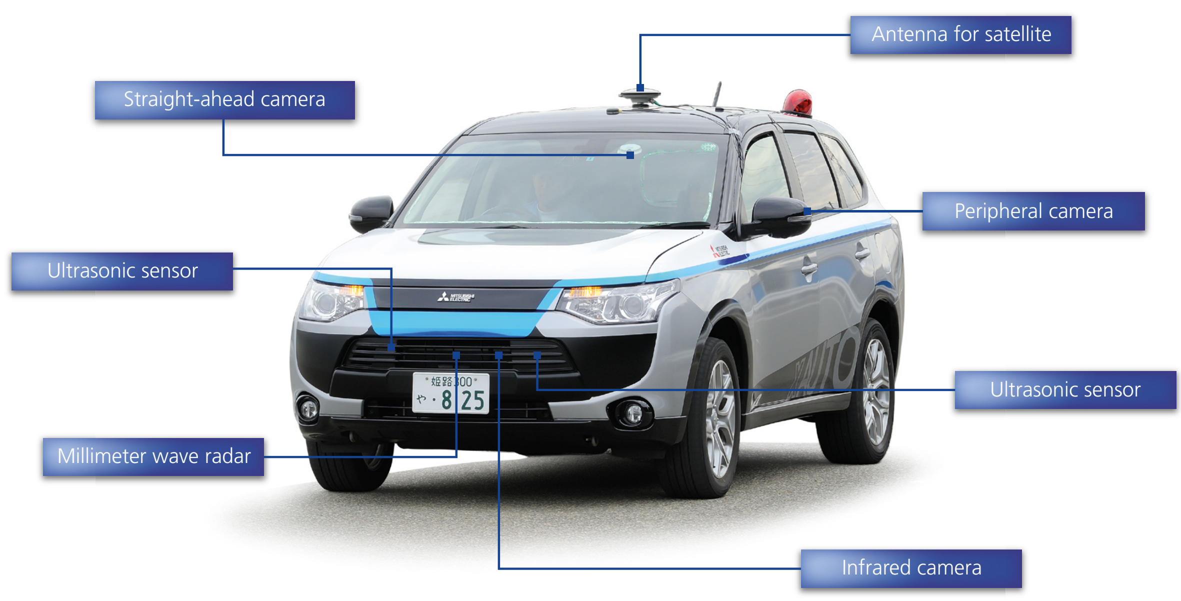
Driving Your Car from Space

Developing a satellite-based autonomous vehicle control system

The vehicle blinks, changes its lane, accelerates, and then stops exactly at the next intersection – without anybody doing anything at the steering wheel. A satellite system, multiple sensors, and dSPACE MicroAutoBox II, with autonomous vehicle steering implemented by Mitsubishi Electric, make this vision a reality.



Overview of the sensors for autonomous driving.

The rapid rise of global interest in the field of autonomous driving is ushering in a new era of automobiles. With many vehicles already offering autonomous preventative safety systems, the addition of improved road infrastructure could increase the reliability and maturity of autonomous driving functions, ultimately increasing the driver's sense of safety.

Autonomous "Diamond Safety" Technology

At Mitsubishi Electric, customers and their safety always come first. Under this motto, Mitsubishi Electric is developing Diamond Safety – a technology that contributes to level 3 autonomous vehicles. Level 3 vehicles are conditionally automated driving systems that perform all driving tasks, but rely on the driver to assume control in certain situations. For example, during highway driving, drivers can take their eyes off the road and let the vehicle take over the necessary driving functions. However, drivers still need to be able to resume control after a few seconds of warning. To verify the suitability of preventative safety technology, Mitsubishi Electric uses MicroAutoBox II, a rapid control prototyping (RCP) system from dSPACE.

High-precision positioning information is provided by the Japanese quasi-zenith satellite system.

Source: © Mitsubishi Electric Corporation

Satellite-Assisted Positioning

Level 3 autonomous driving cannot be achieved with vehicle systems alone. The Japanese quasi-zenith satellite positioning can be employed to obtain high levels of precision and safety. The Quasi-Zenith Satellite System (QZSS; nicknamed "MICHIBIKI") uses multiple satellites that have the same orbital period as

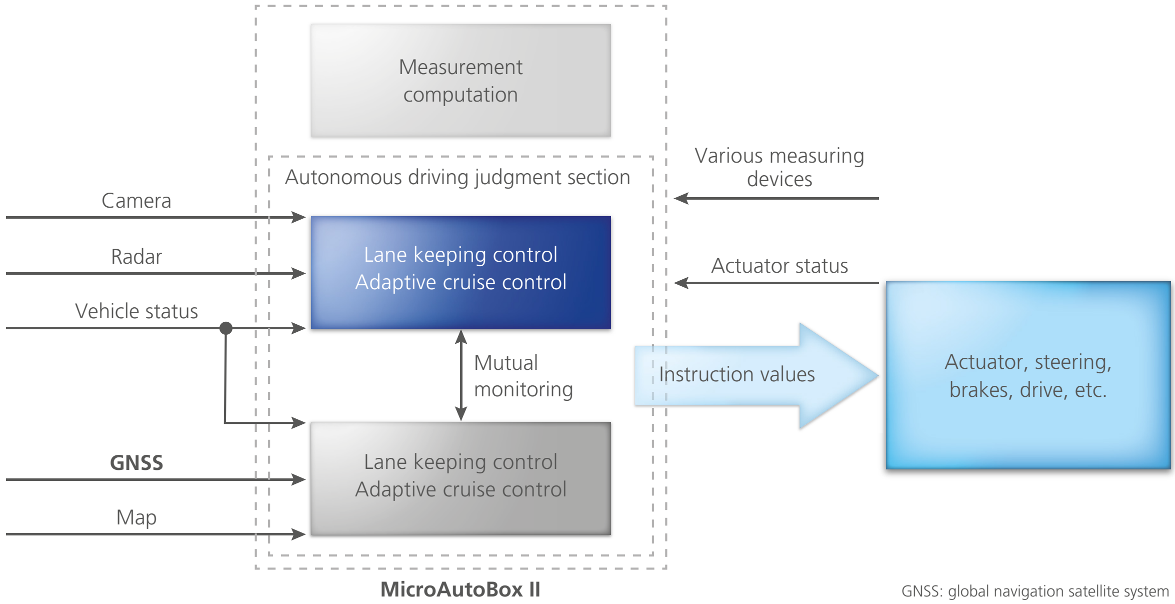


Diagram of the vehicle control system configuration.

geostationary satellites with some orbital inclinations (their orbits are known as quasi-zenith orbits). These satellites are placed in multiple orbital planes so that one satellite always appears near the zenith above the region of Japan. The system makes it possible to provide a highly accurate satellite positioning service covering close to 100% of Japan, including urban canyon and mountain terrain. The QZSS transmits its specific augmentation signals (centimeter level augmentation information) in addition to the current positioning signals. The first satellite was launched in 2010, and by 2018, the system will feature three quasi-zenith satellites and one geosynchronous satellite. By 2023, the system will operate seven satellites to enable continuous positioning. Data received from satellite positioning systems provides the vehicle with a high level of accuracy and reliability for functions such as lane keeping and lane changing.

>>

Dashboard of the vehicle equipped with the autonomous driving features.

Autonomous parking initiated with an external device, e.g., a smartphone.

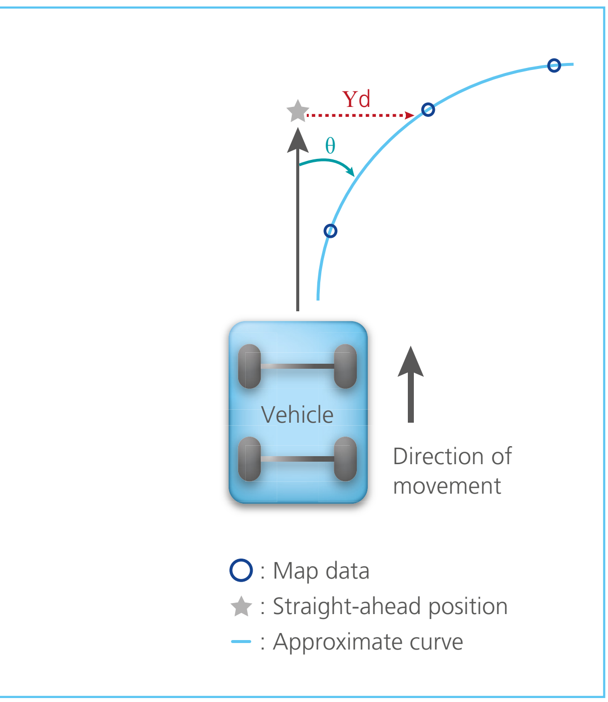


Illustration of the lateral vehicle control.

System Design Overview

The vehicle control system, implemented completely on the MicroAutoBox II, analyzes a multitude of sensor and vehicle data, including data from autonomous driving and infrastructure components, such as the forward camera, millimeter wave radar, high-precision GNSS (global navigation satellite system) receiver and a high-precision map. For example, the function of the lane keeping system makes highly reliable autonomous driving possible by correlating the target driving path based on the white-line recognition with the forward monitoring camera and the target driving path obtained from a high-precision map and high-precision positioning. In addition to vehicle speed, this data is augmented by other vehicle information, which is an input for executing autonomous features and operating the actuators.

Autonomous Vehicle Control

The lateral control of the vehicle utilizes a forward-looking model, as illustrated on the left. The forward position of the vehicle at a future point in time and the target driving path are compared and expressed by the lateral deviation Yd and the angle θ. Then, steering control is executed by using Yd, θ, and additional vehicle information. Vehicle control in the longitudinal direction is executed by the system through speed and brake controls. Speed control is performed by comparing the speed limit data provided by the map, and brake control, except for emergency braking, is set for a smooth deceleration. Stops, such as at an intersection, are executed on the basis of map data.

ControlDesk and MicroAutoBox II for Verification and Control

The dSPACE development tools allowed for a quick implementation of control algorithms developed with MATLAB® and Simulink®, making it possible to test new solutions immediately and adjust control parameters online. This is especially

The MicroAutoBox II in combination with other equipment performs the autonomous driving functions.




> "Using MicroAutoBox II and ControlDesk lets us perform and evaluate tests with a very high level of efficiency."
>
> *Kazuo Hitosugi, Mitsubishi Electric Corporation*

useful as systems gain in complexity. The tools are able to connect various sensors required to verify functions and alleviate communication delays. The abilities considerably reduce the number of items to be verified, thus improving productivity and liberating resources that would otherwise be required for analysis in different departments. If a system has the RCP equipment installed, the experiment software dSPACE ControlDesk allows the control and monitoring of various parameters on one screen, e.g., visually switching vehicle controls on and off and monitoring the input/output values of various interfaces and computational values. Additionally, with its multiple interfaces, MicroAutoBox II allows for easy vehicle operation and real-time monitoring of data from measurement devices. As a result, any evaluation can easily be completed.

Hideyuki Tanaka,
Mitsubishi Electric Corporation

Mitsubishi Electric's team of developers for the autonomous vehicle steering system.

Back row (standing, from left to right): Yu Takeuchi, Kenta Katsu, Yuji Shimizu, Kazuo Hitosugi, Takatoshi Kakuta, Tsuyoshi Kichise. Front row (squatting, from left to right): Kazuhiro Nishiwaki, Hideyuki Tanaka (Senior Manager), Toshihide Satake, Michitoshi Azuma, Rei Yoshino.

Conclusion and Outlook

The Diamond Safety technology has already reached a high level of maturity and scope of functionality. The principle of autonomous driving was successfully demonstrated on various test tracks. Our plan is to introduce individual safety functions of this technology into series production step by step. We would like to continue advancing the development of the high-level autonomous driving control system by using dSPACE products.