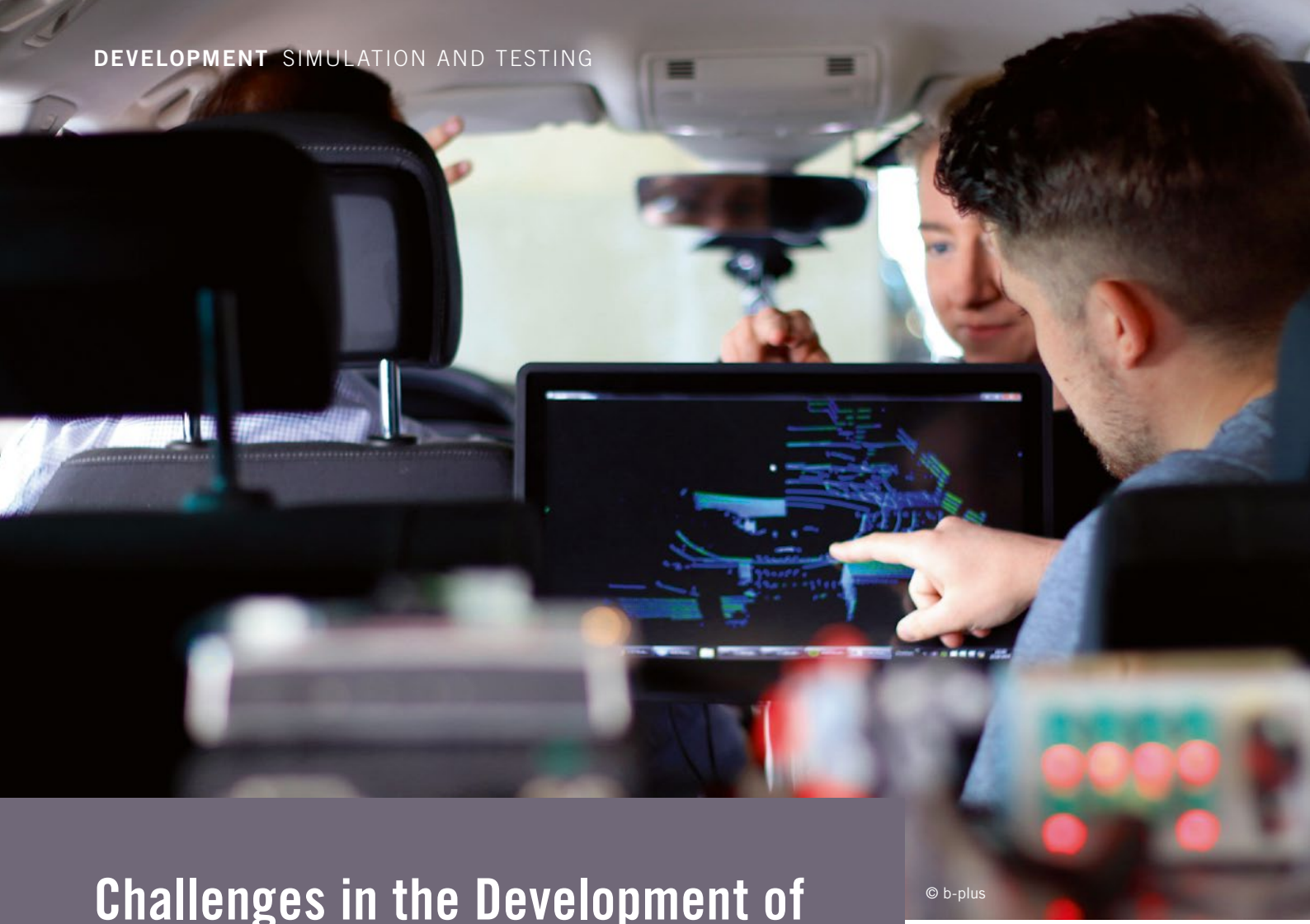

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Challenges in the Development of Control Units for Automated Driving

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Automated driving will further increase the amount of measurement data that has to be recorded and managed in the development and application of the systems in the future. In the following, b-plus highlights the challenges from the perspective of a measurement equipment manufacturer.

INCREASING REQUIREMENTS

The complexity of autonomous driving, the associated sensor control units or domain controller technologies as well as other diverse development steps have been presented from many perspectives in recent years. But against the background of high data volumes in the vehicle, what are possible approaches for autonomous driving systems from the point of view of a measurement equipment manufacturer? How can the development and validation effort, which is already subject to high costs and time expenditure, be optimized?

A decisive success factor is to set the right course already at the stage of project initiation in order to avoid problems in the further course of the project. The measurement equipment manufacturer b-plus, who is specialized in raw sensor data and also has project experience in the development of Electronic Control Unit (ECU) software for Automotive Driver Assistance Systems (ADAS), explains methods for achieving this goal in the following. This includes a clear sensor definition, the consideration of the specific sensor interfaces, and the definition of the ECU development data required by the developer. In addition, the interdepartmental coordination with

regard to the requirements for measurement technology is highlighted. Furthermore, the planning of all test stages before the complete-vehicle test, especially in order to define the requirements for the environment of raw-data reinjection, is also discussed in detail.

SENSOR DEFINITION WITH FOCUS ON MEASUREMENT EQUIPMENT

It is often difficult to define the sensor technology in detail before the project starts. However, this is essential for planning the subsequent steps. For an exemplary development of a sensor ECU, not only the sensors connected to the ECU must be considered, but also interfaces for additional measurement equipment. Wide-angle cameras are required so that the measurement technology can record, for example, interior surveillance parallel to the driving scene detection. Additionally, depending on the object of development, several lidar (light detection and ranging) systems for near-field monitoring or a 360° lidar sensor that provides a bird's eye view of the entire vehicle environment may be needed. If the ADAS measurement technology is not completely defined, it can occur during the course of the project that interfaces at the measurement equipment are not sufficient or that the maximum recordable data rates are exceeded. This results in the inevitably purchase of additional measurement technology systems, which in the worst case are outside the time synchronization (for example Ethernet time synchronization IEEE1588 802.1AS) of the other sensors and thus provide the developer with incorrect relations to the respective data. Here, it should be ensured that even in the case of unforeseeable events there is still the possibility for flexible expansion without negative consequences, **FIGURE 1**.

CONSIDERATION OF THE SPECIFIC SENSOR INTERFACES

When considering the sensor interfaces that are directly coupled to the ECU, it is particularly important to consider the data extraction method of the sensor to be developed. MIPI CSI-2, with sideband signals such as I²C, is often used as an interface. If the distance between camera and ECU is greater, MIPI CSI-2 must be converted using serializer/deserializer components to bridge this distance. The type and manufacturer of these components as well as their often very specific configuration are relevant in this case. This information must be reflected in the measurement technology in order to be able to tap the data with a suitable measurement data interface. The data is transported to the recording system as well as parallel to the ECU with the lowest possible latency time.

Furthermore, the transfer route must be addressed. If the converted data is transported with the serializer/deserializer components, for example via a coaxial cable, it may be necessary to use appropriate filter circuits as well as an additional power supply for the sensors in the hardware of the measurement interface, which are specified by the manufacturer. Therefore, it is important to involve the measurement equipment manufacturer at an early stage. Depending on the setup, a measurement technology interface must be developed or may change depending on the development status of the ECU prototype, thus requiring a redesign of the measurement technology interface. In addition to the hardware interface, input data such as image format, resolution, color depth, and frame rates are essential. According to the requirements for the input data, implementation efforts in the Field Programmable Gate Array (FPGA) or in the software may be necessary.

DEFINITION OF THE ECU DATA REQUIRED

If the ECU and the required signals, which are used in the E/E and function

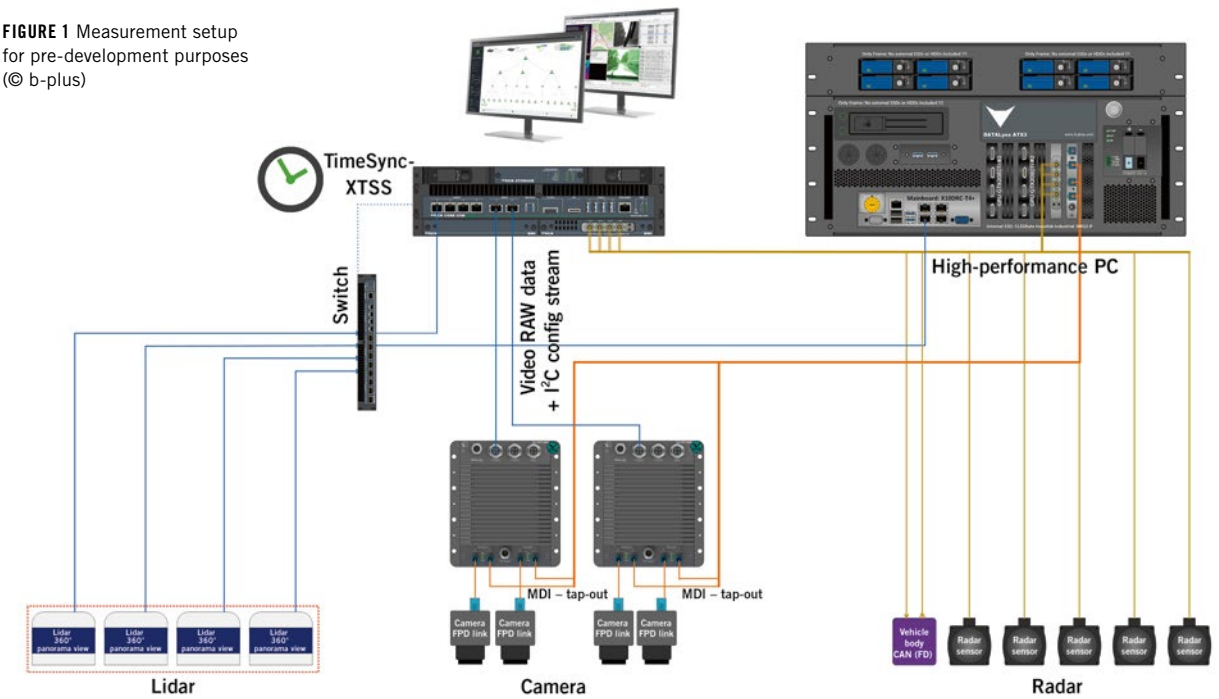

FIGURE 1 Measurement setup for pre-development purposes (© b-plus)

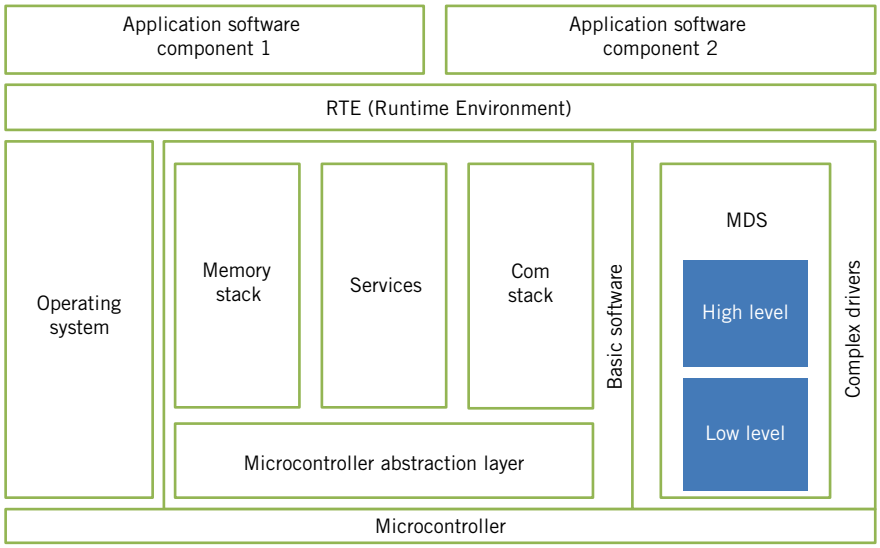

FIGURE 2 Example of a planned Measurement Data Service (MDS) in the ECU software architecture (© b-plus)

development, are considered, it must be clarified which additional software interfaces are needed, such as an Autosar compatible interface for the measurement data packets. In addition, the use of software interfaces for data description or operating-system monitoring, such as for runtime monitoring, might be necessary. These and other topics must be taken into account and coordinated in the project setup. Due to the use of so-called Parser components that must be compiled with the ECU code, this usually happens at the same time as sensor ECU development. If corresponding monitoring mechanisms are integrated on the controller, this integration offers the benefit of simple and targeted error detection when problems arise, especially with ECUs that are increasingly connected to each other in the context of autonomous driving, **FIGURE 2**.

INTERDEPARTMENTAL COORDINATION

Of course, interdepartmental coordination is already being carried out by ECU developers. However, in ADAS development there is a larger area that needs to be included or reintegrated. In conventional powertrain projects, it is sufficient to provide a corresponding interface protocol such as XCP, for example via CAN, assuming that the other departments are able to handle it. After all, these technologies have already been tested and implemented for many years. In the ADAS environment, however, several new sensor manufacturers are currently entering the market, using different technologies. In addition, the raw data extraction, as already described above, requires additional mechanisms to be combined. This includes, among other things, the decoupling of the sensor interfaces and the consideration of the internal ECU signals.

In the context of domain controllers, the consideration of new technologies and their interdepartmental coordination becomes even more important due to insufficient experience and new manufacturers. At the beginning of a project, it is crucial to take into account which data should to be recorded with the recorder system and how it is to be recorded. Mechanisms such as a forward-writing file format or a ring-buffer offer a number of benefits for these data volumes. If unpredictable problems occur with the system, the files are readable with a forward-writing file format, and the test results can be used.

The raw data interpretation must also be clarified in time. This is necessary to enable the existence of a mechanism in the framework for the raw data extraction, for example for image data, in order to realize the further processing and version-stability of data. This allows the continued use of visualization objects generated in the develop-

FIGURE 3 Possible b-plus measurement technology installation in a test vehicle (© b-plus)

ment process. As a result, they do not have to be modified with every subsequent ECU adaptation, especially in connection with a data description, for example via a Measurement Data Service (MDS). A revision would require a lot of time and effort, in particular with the large variety of ADAS sensors.

When visualizing the raw data, it is important to pay attention to the resources used. Often free software packages are applied which are not free from copyrights of third users. Furthermore, for high data rates, often exceeding 1 GByte/s, it is necessary to make agreements. These can specify, for example, if parallel scenario detection is required in addition to recording, which results in a more intelligent distribution of measurement data due to the need for high-performance graphics computing. This is important as in some cases recording and detection/visualization cannot be run at the same time.

PLANNING OF ALL TEST PHASES

Coordinating all requirements completely is a great challenge for the development departments. In this context, great attention must be given to the test level validation steps. As soon as the data is stored in a data center using a suitable station for the recorder system, it must be defined how this data can be reinjected in the early development process. On one side, this includes Software-in-the-Loop (SiL) mechanisms, which have to be implemented in the framework. On the other side, a component Hardware-in-the-Loop (HiL) system must be set up with the recorded raw sensor data, which is usually only addressed in everyday project work when the recordings are already available. To start in time, this must preferably be discussed and defined in parallel with the first two points. One needs to pay attention to how the ECU is installed in the device or where the raw data is tapped and injected again, for example before/after Integrated Signal Processing (ISP), **FIGURE 3**. In the case of raw-data injection, further mechanisms are necessary to synchronously reinject the large amount of data from different sensors and interfaces or to synchronize it with other devices. In addition, emulations of side-band signals such as I²C or Serial Peripheral Interface (SPI) are often necessary in order to protect the ECU from possible error detection.

CONCLUSION

Additionally, to the challenges of today, some measurement technology concepts have to be reconsidered for the future. Topics like Remote Direct Memory Access (RDMA) are essential for future domain controller data rates. For the future, it can be noted that an early integration of the measurement equipment manufacturer or even a system supplier with regard to the measurement toolchain is necessary to avoid parallel development of a measurement toolchain besides the usual project challenges of a sensor ECU manufacturer during product development.