

Calibration Data Management – A Puzzle Game no more

Manage Complex Calibration Data at the Individual Workstation, in Teams and Throughout the Company

In ECU development, short innovation cycles and high cost pressure lead to a distribution of work, in which the software development process is separate from the process of adapting it to its desired behavior in the vehicle. In today's vehicles, tens of thousands of such calibration data values must be determined and managed – and indeed for each individual vehicle variant. To avoid errors, quality standards are needed that have the same level as in the development of the actual software. This article discusses the requirements of tools for managing parameter values and presents a universal solution.

In the functional development of ECU software, high quality standards (SPICE, CMMI) must be maintained. The correct parameterization of the ECUs is as crucial as the correct functionality of the software in the ECU. Consequently, modifying parameters must meet the same quality levels. This modification is referred to as "calibration" which is essential for process adherence and quality assurance to trace calibrations precisely and to ensure consistent parameterization of every conceivable variant.

The trend toward shorter innovation cycles and more stringent requirements for quality and efficiency make it essential to achieve a higher degree of reusability. It must be possible to reuse the software in many models and vehicle variants in developing electronic systems. Each variant in an ECU leads to a separate parameter set, and this increases the number of parameter sets substantially.

Today, around 60,000 parameters must be calibrated in the ECUs of a diesel engine that conforms to the Euro-6 emissions standard. Although ECUs in the chassis and car body areas involve fewer parameters, they typically exhibit higher numbers of variants, and this also requires a dedicated data management solution. In summary, the manufacturer of an automobile today must generate and manage thousands of parameter set files.

Improving Quality with a Clearly Structured Process

The use of a special data management solution offers significant help in the complex process of managing calibration data. It guarantees that the thousands of parameters are used in the correct variants in precisely defined combinations for hundreds of vehicle calibrations. At the same time, each change must be precisely traceable for quality assurance purposes (**Figure 1**).

Such a clearly defined approach creates process reliability and increases data quality. The original files of the engineers who maintain their work results in a Calibration Data Management (CDM) system are subject to version management. This means that the user can tell at a glance which parameter sets have flowed into a specific variant and where they are being reused. This assures automatic updating of a new parameterization version in all relevant variants. Within the project, a quality and maturity level model helps in documenting changes for data integration and monitoring the progress of the project. The CDM system takes a multi-stage approach to data integration. After all results from the calibration engineers have been delivered into the system, it is able to resolve conflicts due to faulty or duplicate parameterization by means of assigned parameter responsibilities and rules. The results can then be validated by the four-eye principle and checked for completeness. Only then is the data ready for consolidation for the next data revision level and release for the next phase. This also facilitates cooperation with development partners, and it assures access to correct data in different competency areas.

Efficiency by Intelligent Variants Management

Along with supporting calibration tasks by providing a clearly structured process, another core task of data management is to productively manage large numbers of calibration variants. A "calibration variant" represents a set of

vehicle attributes such as engine displacement, transmission type and emissions standard. The different product configurations require changes to the parameterization of the ECU software, and they are referred to as "derivative calibrations".

Variant management provides mechanisms which ensure, for example, that all variants automatically get consistent parameterization – thereby avoiding unnecessary redundant work. For parameters that depend on system attributes, rules are used to describe dependencies. This guarantees consistent parameterization of all variants with identical system attributes without additional work.

Think Big, Start Small

A company's adoption of a CDM solution rarely done in one big step, but frequently, solutions emerge for specific challenges that come up in performing specific tasks. For instance, a calibration engineer might need assistance in distributing work results to all calibration derivatives. Or a project leader needs to resolve or avoid conflicts which occur when calibration data is entered into the system by team members. The proliferation of such insular solutions makes a unified data management solution for the entire company increasingly all the more important. A central CDM solution can represent the entire process and supports adjacent areas such as software development and validation (**Figure 2**).

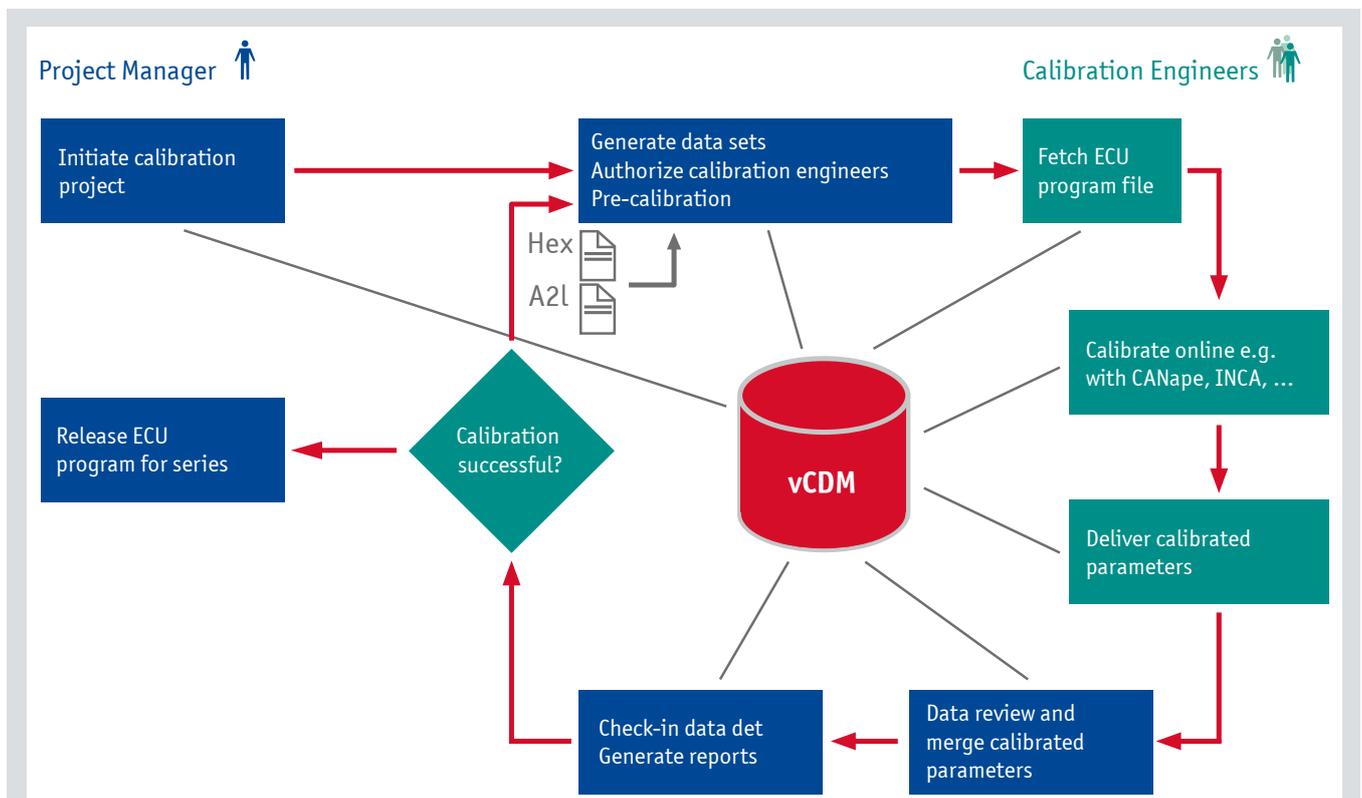


Figure 1: The CDM System offers a clearly defined process that leads to substantial quality improvements in the calibration of ECUs.

That is why it is helpful for the data management solution to satisfy the specific requirements of a calibration engineer as well as those of a team and the entire company. Such a scalable solution can be introduced and built up stepwise, while protecting investments.

Data Management for the Calibration Engineer

In the ECU calibration process, the engineer first evaluates the initial behavior of a system component using software tools (MCD tools) on the test bench or in the vehicle. The engineer then adjusts the parameters towards attaining the target behavior. However, this "online calibration" approach only represents part of the required work.

Frequently, it is also necessary to compare and edit the parameters for different vehicle variants without a direct connection to the ECU (offline calibration). This is the case when parameters are "pre-calibrated" with values based on the requirements of software development, when the results of similar prior projects are adopted, when values are copied from online calibration to different variants or when numerical methods are used for model-based optimization.

For these tasks, the calibration engineer needs a tool with a user interface similar to Microsoft Excel, in which parameters (rows) can be shown together with calibration variants (columns), and any of the parameter values can be edited. In addition, the tool must support the special requirements of calibration (ASAM standard formats such as CDF2.0, characteristic maps, diagnostic information).

Cooperation on a Team

ECU calibration is largely teamwork. These teams frequently consist of members from different companies (automotive OEMs, ECU suppliers and engineering service providers). With increasing globalization and specialization, efficient co-working of calibration teams is continually gaining in importance. It must be possible to distribute work results quickly. Networking via e-mail and Internet is helpful - however - a lot of manual work steps are often required to exchange data between different systems. This is a process that is time-consuming and prone to errors. The data management system now gives teams the ability to automatically distribute the information. Integration of the e-mail system informs all participants about data changes, new releases and software changes. This guarantees that the teams are working with identical data in a timely manner.

Just as important as automated distribution is the availability of data at work sites with difficult network connections. Ideally, an engineer should be able to "check out" a calibration project from the central database on a laptop, so that it is available in the local network for shared access.

Data Management in the Enterprise

A solution for data management is closely linked to the tool chain for developing electronic systems. Changes to the calibration data have a direct relationship to requirements management systems, change management systems and many other ALM applications (ALM: Application Lifecycle

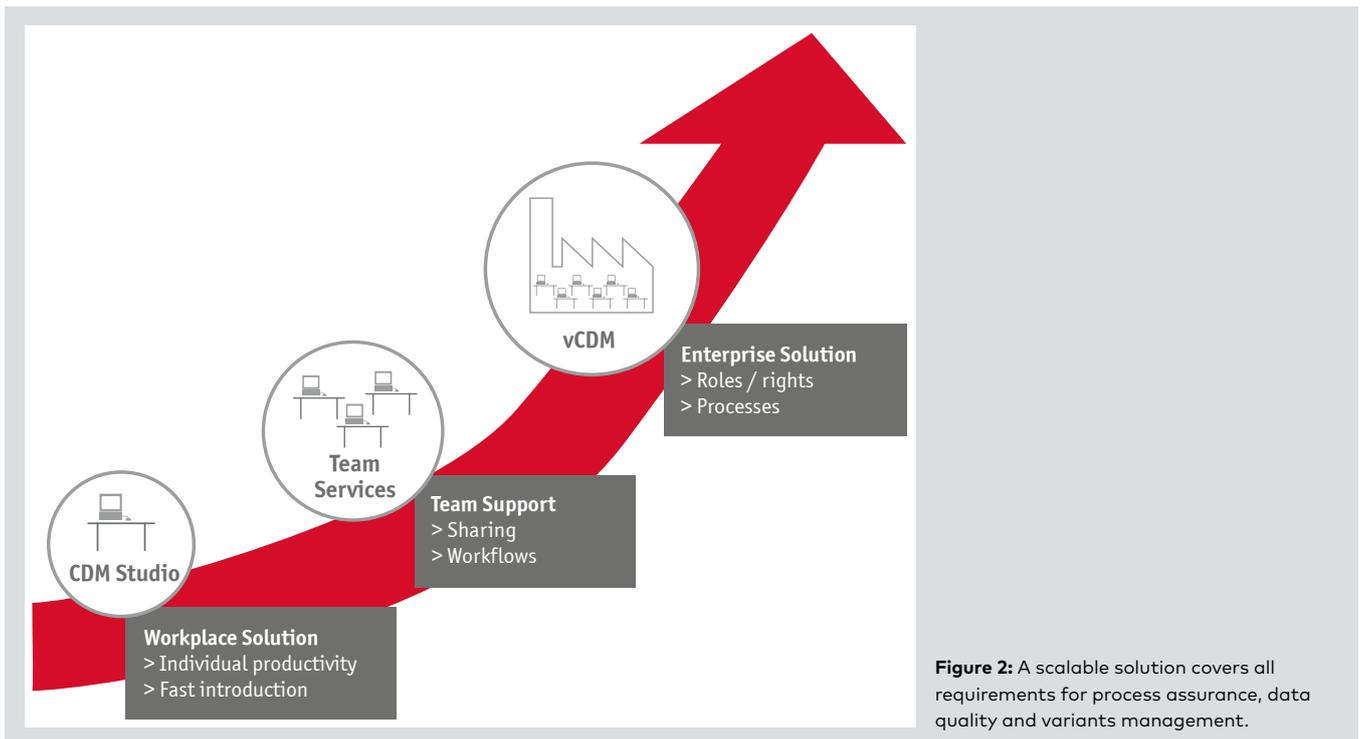


Figure 2: A scalable solution covers all requirements for process assurance, data quality and variants management.

Management). Efficient CDM systems exhibit high flexibility and can be integrated in existing systems via automation interfaces, APIs (Application Programming Interfaces) or Web services. An integration with OSLC (Open Services for Lifecycle Collaboration), for instance, makes it possible to implement universal traceability of changes.

High Acceptance by Adapting to Specific Aspects

A CDM system has specific requirements when it is used across different technical areas. That is because the work procedures for calibrating a chassis controller differ noticeably from those for an engine controller. The different requirements of the domain and the business organization result in different methodologies. When introducing data management it is important to represent the different work modalities of the technical departments as ideally as possible, instead of prescribing a “standard process”.

A Scalable Solution for all Uses

High levels of calibration data quality, process adherence and efficient variant management are the primary prerequisites for successful calibration projects. Vector offers a scalable CDM product with solutions ranging from the individual calibrator to calibration departments and the complete company-wide solution.

For the calibration engineer, “CDM Studio” serves as an efficient tool for editing parameter set files (**Figure 3**). The parameters generated in the ECU calibration process can be conveniently displayed, compared and edited. Due to the many different import options it can be used throughout the complete process – from software development in MATLAB to online-calibration. CDM Studio supports all commonly used measurement and calibration tools such as CANape, INCA, MARC and others.

When multiple calibrators work on a team, solutions are needed for reliable data storage and data management. “vCDM” is a database-supported platform for calibration teams and the entire company. The system avoids data conflicts with work packages and assigns parameter responsibilities. It detects and resolves parameter conflicts and enables seamless tracking of data changes.

A large number of variants can be handled reliably by managing dependencies, automatically computing parameter values and reusing work packages. This leads to consistent calibration variants with higher data quality, which can be used in data mining and report functions for further quality and efficiency improvements. Finally, the integrated CDM Studio is used to graphically display and process the calibration data. This results in a scalable solution with the same look and feel, so that users can easily switch between different applications.

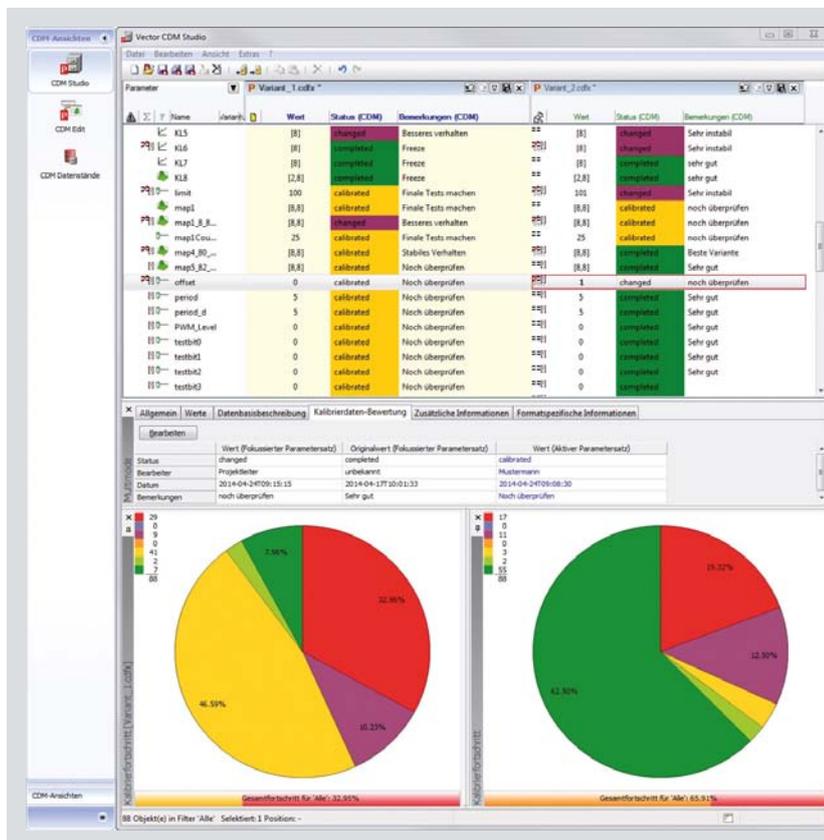


Figure 3: CDM Studio shows the status of ECU calibration in a well-organized layout.

Conclusion

In ECU calibration, tens of thousands of data values must be determined and managed for each individual vehicle variant. To attain the required quality, it is necessary to have an assured process and universal tool support. It is also essential to consider the individual working methods of different departments and businesses.

Wolfgang Löwl (Group Leader in Tool Development at Robert Bosch GmbH, Powertrain Area): "Together with Vector, BOSCH developed a high-performance CDM system which fully met our special requirements. We have been using it successfully for 10 years now."

Outlook

In the future, it will become increasingly more important to utilize the enormous quantities of data – not only to improve quality, but to also add value. For example, data mining algorithms and model-based calibration can be used to automatically generate new calibration data sets from the history of existing calibration data. These data sets can then be validated with special models. In the future, this will make it possible to shift increasing numbers of tasks from the vehicle to the office.

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Website Vector: www.vector.com

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**Stephan Herzog**

is employed at Vector Informatik GmbH as a Business Development Manager responsible for the Measurement and Calibration areas.

**Andreas Patzer**

is employed at Vector Informatik GmbH as team leader in the Measurement & Calibration product line; he is responsible for Customer Relations and Services.

**Michael Vogel**

is employed at Vector Informatik GmbH as Business Development Manager responsible for vCDM.