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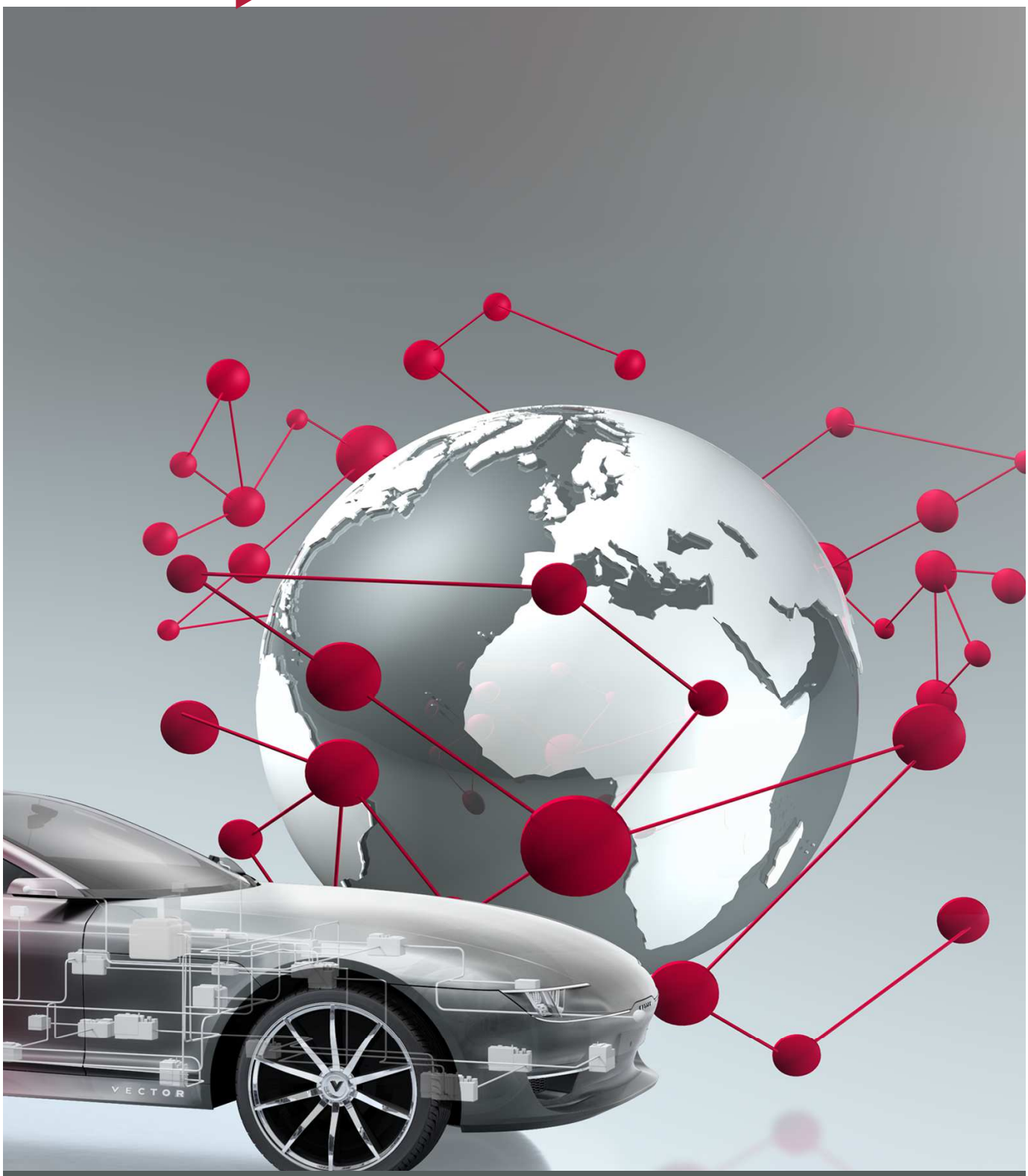

vCDM

vCDMstudio – Option vCDM - vCDMcenter

Product Information

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V3.0 10/2020 – Valid for vCDM from Version 19.

1 Introduction

1.1 Challenges in ECU calibration

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 calibration data values must be determined and managed for each individual vehicle variant. To avoid errors, quality standards are needed for calibration data similar to those used in the development of the embedded software.

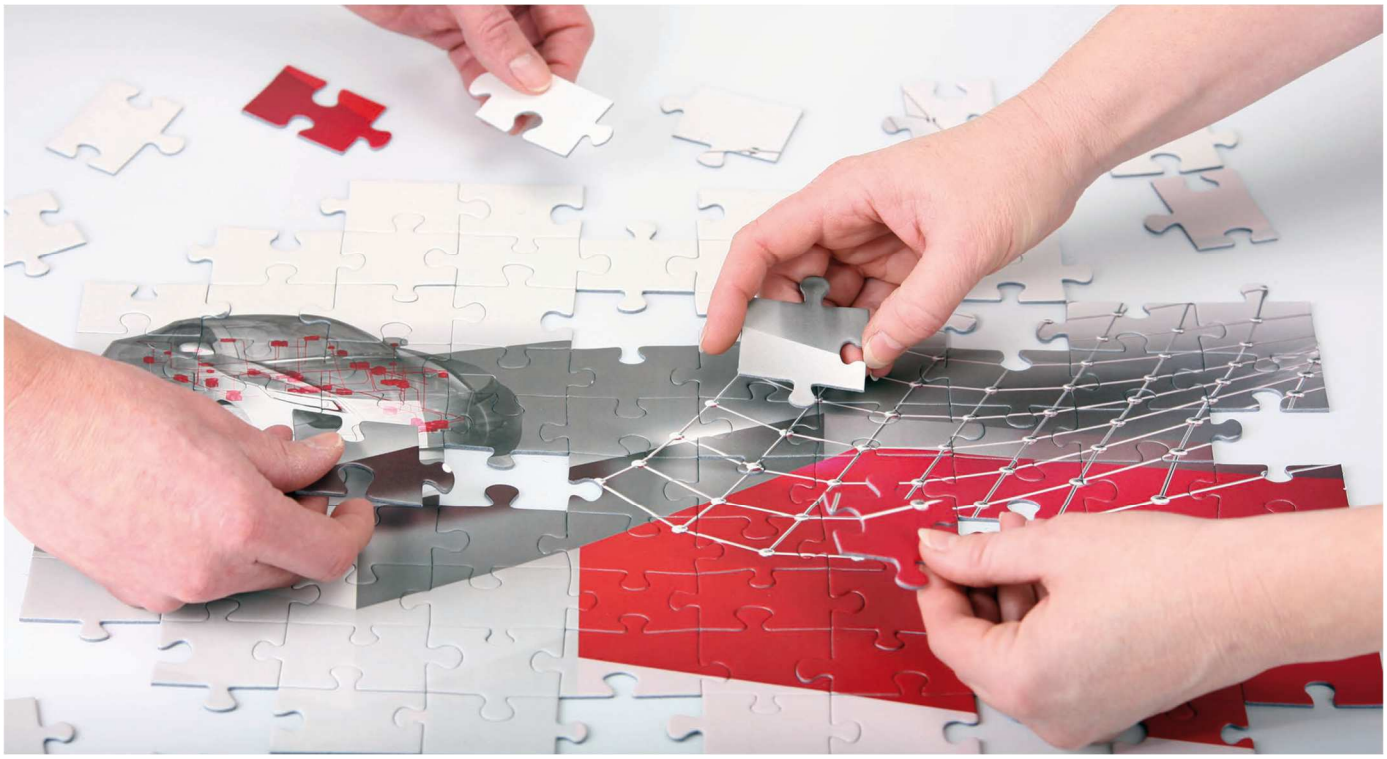


Figure 1: Is your calibration process a puzzle game?

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. It is essential for process adherence, legal compliance 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. Each variant of an ECU leads to a separate parameter set, and this increases the number of parameter sets substantially.

Today, some 80,000 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, OEMs and their Tier-1 suppliers must generate and manage thousands of parameter set files. The use of a special-purpose data management solution offers significant support 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.

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 immediately 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 help 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 -or- by defined rules 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.

1.2 The vCDM Solution

vCDM provides a scalable solution that delivers high productivity for individual calibration engineers, small teams or the complete enterprise. **vCDMstudio** is a powerful workbench for calibration data. It includes data set management for local files and can easily be used with all other tools for calibration. **Option vCDM** can be used with Vector CANape, or with single user vCDMstudio to connect the local data set management with the multi-user vCDM database. **vCDMcenter** is used by data set managers to create and configure calibration projects in the vCDM server. It can also be used by calibration engineers to use calibration projects and contribute calibration changes.

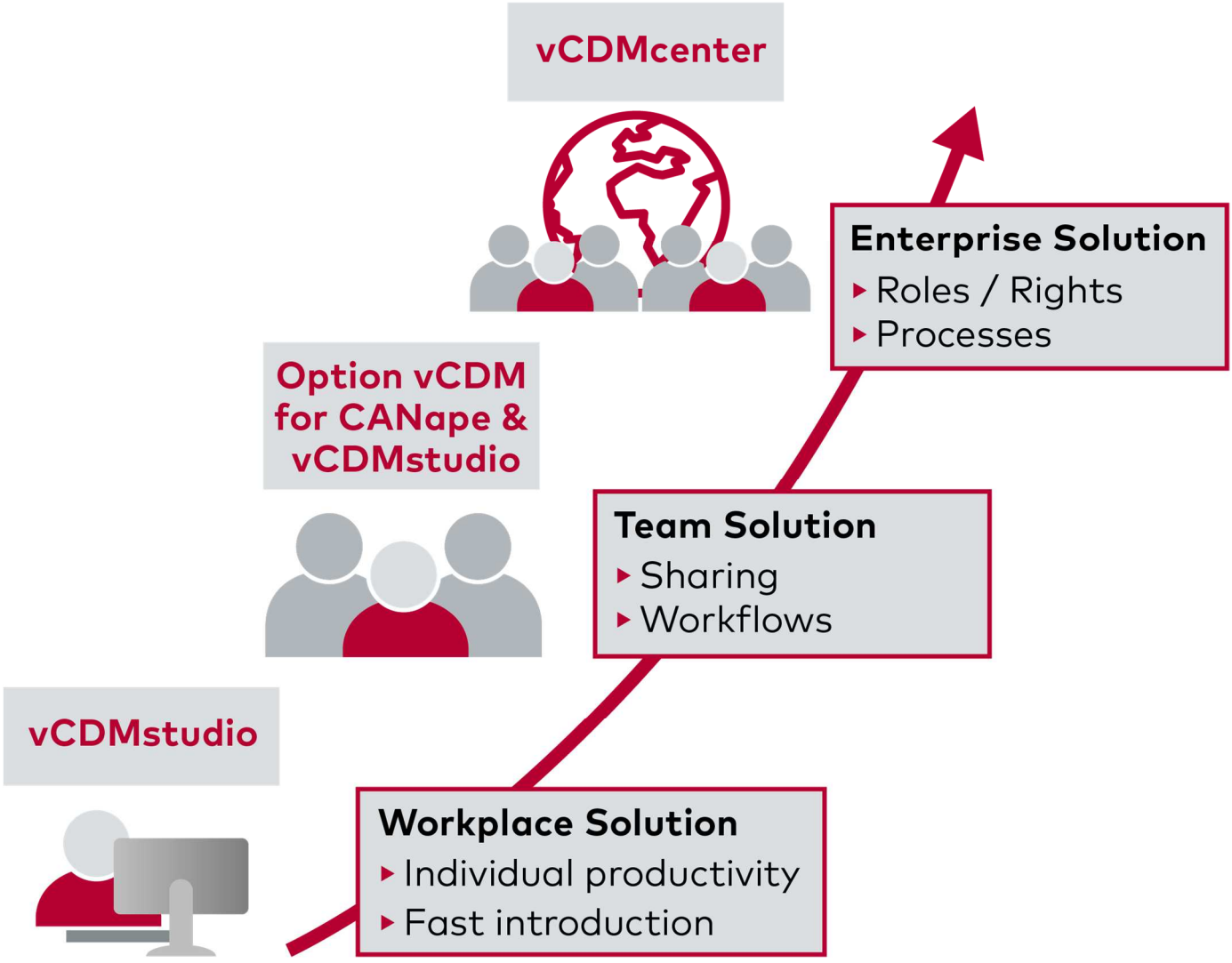


Figure 2: vCDM – A scalable solution for Calibration Data Management

Capability / Product - Matrix	vCDMweb	vCDMstudio	Option vCDM (CANape & vCDMstudio)	vCDMcenter
Target user profiles	Consumer of calibrations, i.e. Testbench	Calibration engineers with local data mngt	Calibration engineers with multi-user, central data management	Calibration engineers, Calibration managers
Reporting and analysis on calibration and maturity	√	√	√(*)	√
Variant data set management and rich meta data	**download only**	**local files**	**database**	**database**
Multi-column edit, copy, compare of calibrations files		√	√(*)	√
Import/Export of arbitrary calibration formats		√	√(*)	√
Calibration check and compute rules		**local files**	**database & flow control**	**database & flow control**
Tracking of changes using the history		**only quality data**	**quality & values**	**quality & values**
Collaborative work on shared data sets			√	√
Detection and resolution of conflicts			√	√
Creation of shared data sets			√	√
Creation of vCDM projects			**using only**	√
Multi-user roles & rights			**using only**	√
Working packages and parameter permissions			**using only**	√
Automatic variant management			**using only**	√
Version management for software and data sets			**using only**	√
Migration of calibration to new software (A2L)				√

Figure 3: Capabilities/Product – Matrix

(*) provided by base product CANape or vCDMstudio

2 A calibrators workbench – vCDMstudio

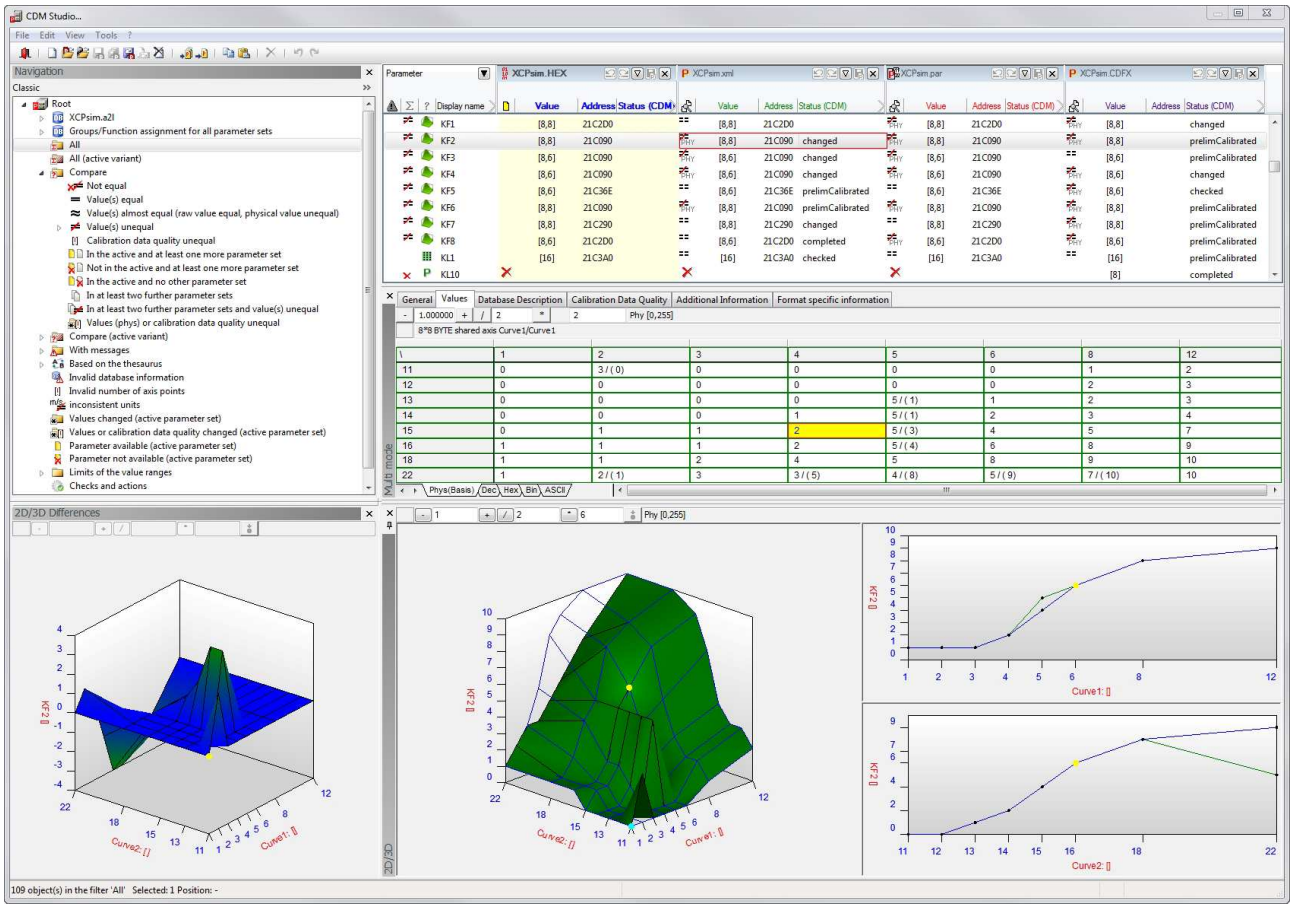


Figure 4: vCDMstudio lets you manage the extensive parameter sets of your ECUs easily and with full traceability

2.1 Excel for automotive calibration data

Its ease-of-use led to a wide adoption of Microsoft Excel – even for automotive calibration data. However – for application in automotive use-cases Microsoft Excel has significant disadvantages. It does not support typical automotive data formats and has no decent editors for maps and curves – to name just a few.

vCDMstudio brings the benefits of Excel to the domain of automotive calibration data. A parameter set contains the values of parameters that are specified in the ECU description file (A2L). vCDMstudio manages these parameter sets and supports all typical file formats. vCDMstudio offers the following functionality:

- Load, visualize and edit parameter sets from symbolic, address-independent parameter set files or from binary files. This makes their processing independent of the ECU program revision level at which the file was generated.
- Simultaneous loading of multiple parameter set files from your calibration process. Because standard formats are used, you can edit parameter files from various tools on the market (CANape, ETAS INCA, ATI Vision).
- User-friendly interface for displaying and editing parameter set files with suitable controls (maps, curves)
- Configurable display of meta-information (Unit, Address, Quality, etc.)
- Execution of various editing steps via an automation interface
- Interpolation is performed when copying characteristic curves and maps with different numbers of interpolation points
- Graphic representation of characteristic curves and maps to efficiently compare differences
- Clever filter mechanisms for defining individual views of parameter sets give users a better comprehensive view
- Generate reports in different formats, e.g. MS Excel format or HTML
- Export and import configurations

Figure 5: Edit parameters in vCDMstudio

Supported File Formats

- DCM, PAR, KON, CSV, CVX, PaCo, CDF2.0. In the XML-based PaCo and CDF formats, additional meta-information can be stored for each parameter value, e.g. maturity level, value history, author, date and comments
- To reintroduce parameter values back to the development process, vCDMstudio also saves the data as an M-script for model-based development and as code files in C, Hex and ASM formats. Here you can use templates to control exactly what the files should contain.
- Modification of flashable binary files from parameter sets in Intel-Hex and Motorola-S formats

2.2 Add extra functionality with Plug-in Apps

vCDMstudio provides application programming interfaces (API) to create your own plug-in Apps. Instead of developing your own tool for the application task from scratch, you can use the powerful functions already contained in vCDMstudio (e.g. parsing the A2L file or writing CDF2.0 files). You only need to implement your own requirements based on this.

Your advantages:

- Integrated, powerful C # development environment to implement your requirements
- Access to standard automotive software functions (read A2L, write CDF)
- Concentrate on solving your actual tasks

The following chapter introduce Apps that come with the base product.

2.3 Ensuring compliance with calibration check rules (Parameter Rule App)

Software algorithms monitor and control essential functions for safety and emissions. Incorrect calibration or configuration can easily result in critical failures or violate legal requirements. This may result in damaged reputation or expensive fines. Consequently, monitoring functional safety and compliance to legal requirements became increasingly important for all engineering domains and calibration data.

A best-practice approach is to capture rules that are used to verify correctness or plausibility of current calibrations. A calibration tooling that supports rule creation and parameter validation throughout the process provides great value to achieve this goal.

The vCDM CSERP Rules (Check for Safety and Emission Relevant Parameters) provide an easy-to-use, domain-specific set of rules that can used by calibration engineers to compile rule sets for validation. The CSERP rules provide checks for ranges, gradients, enveloping curves and many more. Logical operators and conditional expressions can be used to formulate complex rules – all without programming skills required. Rulesets can be combined and re-used.

With programming skills it is even possible to extend the rules by scripting.

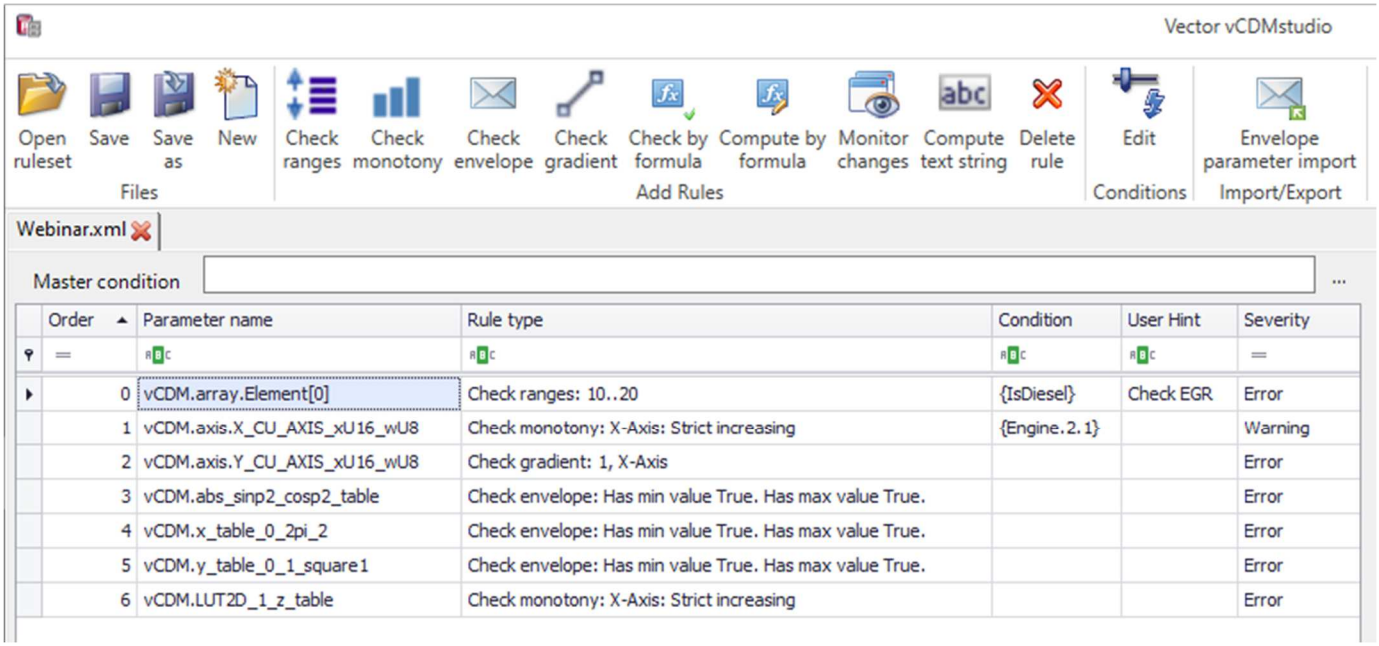


Figure 6: vCDM Ruleset Editor

vCDM offers various check points to validate the current calibrations against such ruleset and log results. One possibility for this is the vCDMstudio Parameter Rule App. Its deployment in vCDMstudio enables using rules even without a complete vCDM solution in the backend – just for local files.

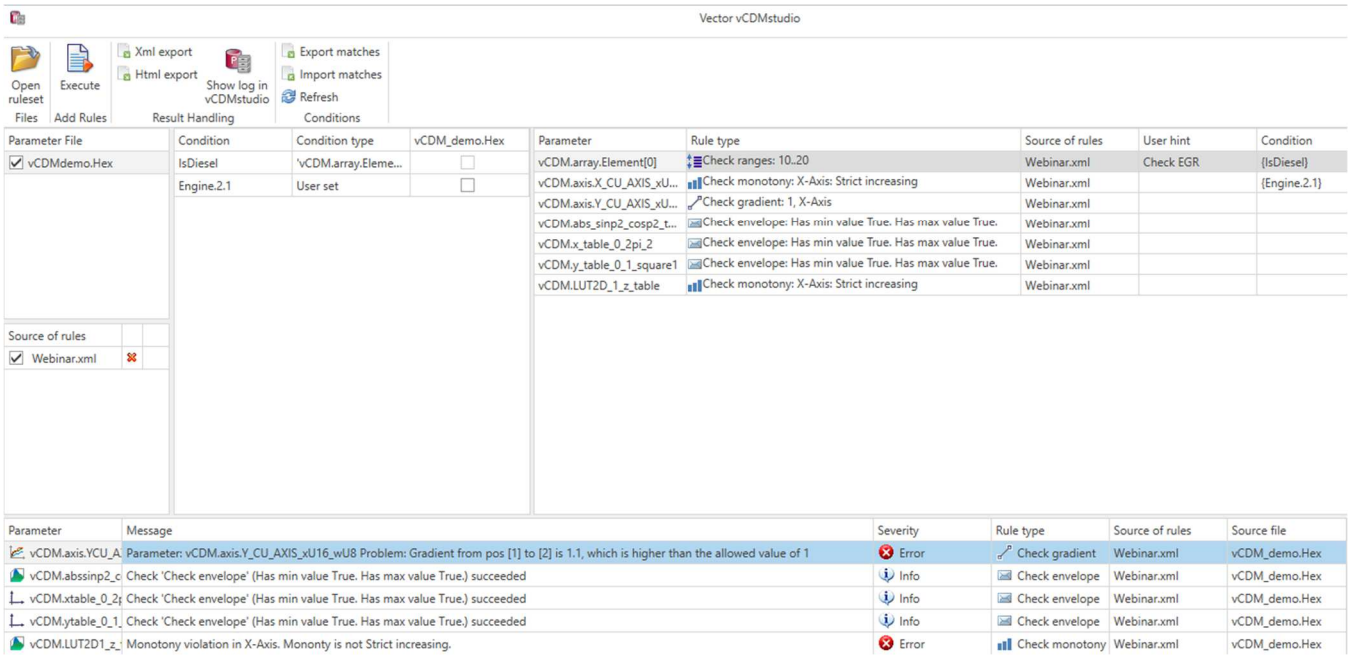


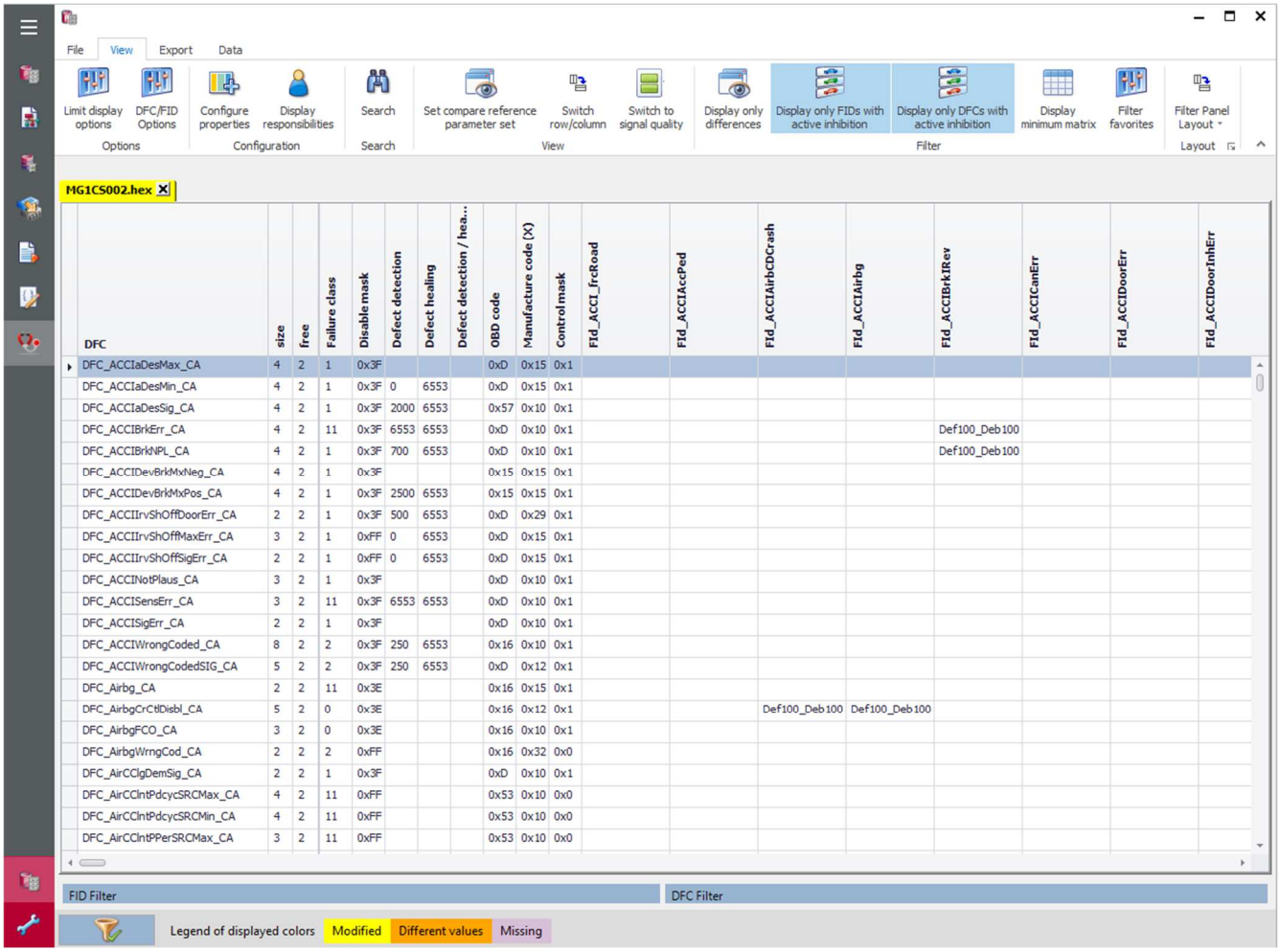
Figure 7: vCDMstudio Ruleset Add

2.4 Function Inhibition Matrix (FIM App)

The FIM-Editor (Function-Inhibition-Matrix) supports Onboard Diagnostic (OBD) calibration engineers in configuring the ECU behavior on diagnostic events. This is a daunting task with a standard calibration tool when an engineer has only the A2L file available. Often it is even impossible because the ECU FIM is implemented in a way that does not expose its behavior in an A2L description.

The FIM editor App presents a domain-specific view on the current HEX/A2L and displays directly the relation of diagnostic events to software functions. Closely related to the function inhibits is the configuration of properties for the diagnostic event. The App enables users to configure the DEM (Diagnostic Event Manager).

The editor is only available for selected ECU architectures.



DFC	size	free	Failure class	Disable mask	Defect detection	Defect healing	Defect detection / hea...	OBD code	Manufacture code (X)	Control mask	Fld_ACCI_frcRoad	Fld_ACCIAccPed	Fld_ACCIAirbCDCrash	Fld_ACCIAirbg	Fld_ACCIBrkIRev	Fld_ACCICanErr	Fld_ACCIDoorErr	Fld_ACCIDoorInhErr
DFC_ACCIaDesMax_CA	4	2	1	0x3F				0xD	0x15	0x1								
DFC_ACCIaDesMin_CA	4	2	1	0x3F	0	6553		0xD	0x15	0x1								
DFC_ACCIaDesSig_CA	4	2	1	0x3F	2000	6553		0x57	0x10	0x1								
DFC_ACCIBrkErr_CA	4	2	11	0x3F	6553	6553		0xD	0x10	0x1					Def100_Deb100			
DFC_ACCIBrkNPL_CA	4	2	1	0x3F	700	6553		0xD	0x10	0x1					Def100_Deb100			
DFC_ACCIDevBrkMxNeg_CA	4	2	1	0x3F				0x15	0x15	0x1								
DFC_ACCIDevBrkMxPos_CA	4	2	1	0x3F	2500	6553		0x15	0x15	0x1								
DFC_ACCIIrvShOffDoorErr_CA	2	2	1	0x3F	500	6553		0xD	0x29	0x1								
DFC_ACCIIrvShOffMaxErr_CA	3	2	1	0xFF	0	6553		0xD	0x15	0x1								
DFC_ACCIIrvShOffSigErr_CA	2	2	1	0xFF	0	6553		0xD	0x15	0x1								
DFC_ACCINotPlaus_CA	3	2	1	0x3F				0xD	0x10	0x1								
DFC_ACCISensErr_CA	3	2	11	0x3F	6553	6553		0xD	0x10	0x1								
DFC_ACCISigErr_CA	2	2	1	0x3F				0xD	0x10	0x1								
DFC_ACCIWrongCoded_CA	8	2	2	0x3F	250	6553		0x16	0x10	0x1								
DFC_ACCIWrongCodedSIG_CA	5	2	2	0x3F	250	6553		0xD	0x12	0x1								
DFC_Airbg_CA	2	2	11	0x3E				0x16	0x15	0x1								
DFC_AirbgCrCtlDisbl_CA	5	2	0	0x3E				0x16	0x12	0x1			Def100_Deb100	Def100_Deb100				
DFC_AirbgFCO_CA	3	2	0	0x3E				0x16	0x10	0x1								
DFC_AirbgWrngCod_CA	2	2	2	0xFF				0x16	0x32	0x0								
DFC_AirCClgDemSig_CA	2	2	1	0x3F				0xD	0x10	0x1								
DFC_AirCClntPdcycSRCMax_CA	4	2	11	0xFF				0x53	0x10	0x0								
DFC_AirCClntPdcycSRCMin_CA	4	2	11	0xFF				0x53	0x10	0x0								
DFC_AirCClntPPerSRCMax_CA	3	2	11	0xFF				0x53	0x10	0x0								

Figure 8: FIM-Editor enables the configuration inhibitions for selected functions based on diagnostic events

2.5 Connecting 3rd-party calibration tools (INCA App)

Customers use different tools for online measurement and calibration. Besides standard applications like Vector CANape many proprietary tools from OEMs or ECU suppliers are used in the industry. Managing offline calibration data with a powerful calibration workbench such as vCDMstudio is an important step and the rich functionality is rarely provided by such proprietary tools. Hence many users want to use vCDMstudio together with their own online tools.

vCDMstudio provides a Plugin App to connect to ETAS INCA

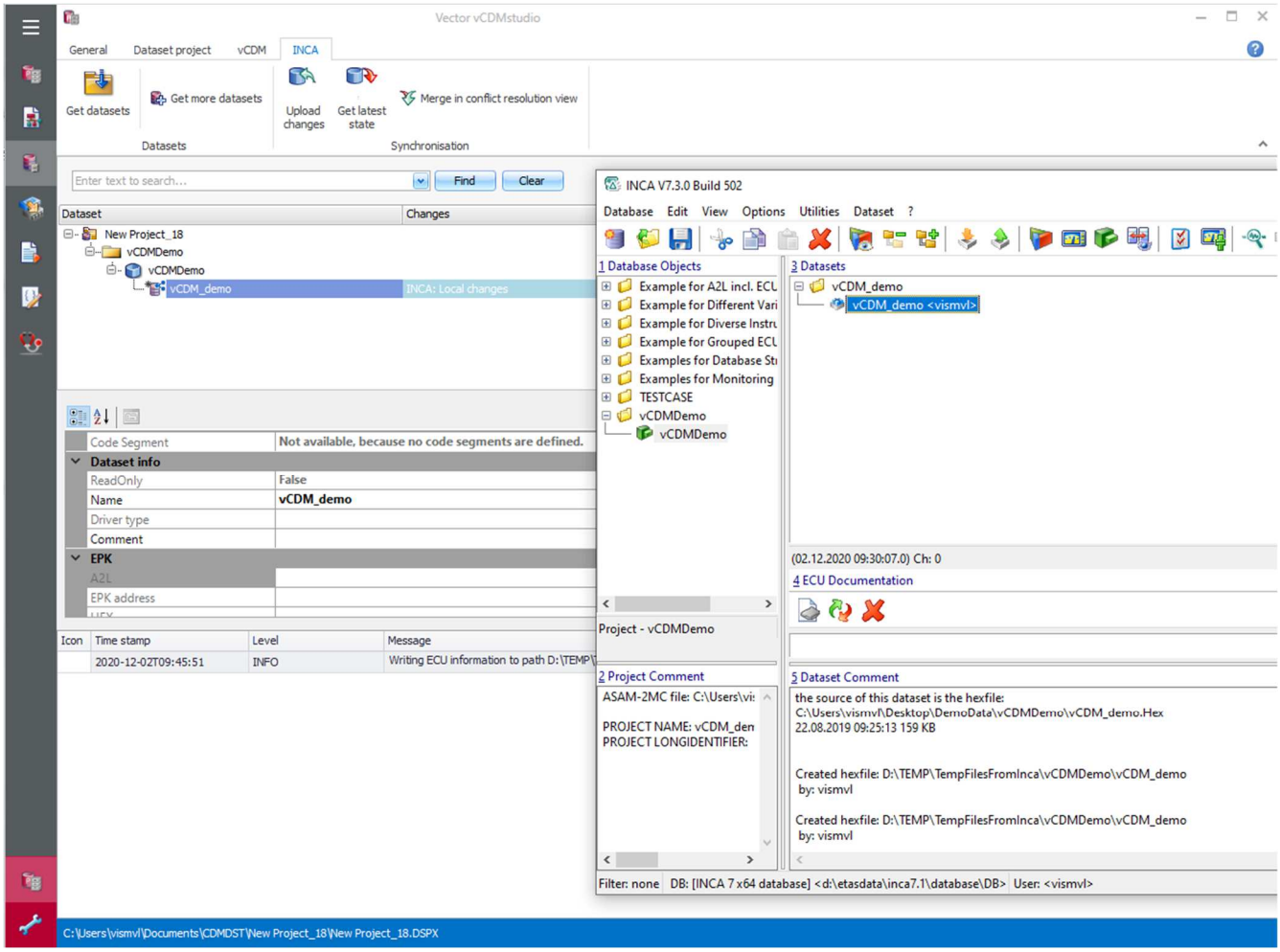


Figure 9: vCDMstudio with standard interface to ETAS INCA

2.6 Data set Management on the local PC (Data set Management App)

Besides its capabilities to work with calibration data vCDMstudio offers built-in calibration data set management. Managing multiple data sets becomes particularly important should you need to deal with calibration variants or software versions.

You can manage multiple local data sets (A2L/HEX) in one data set project. The data set project is stored in a folder structure in the local file system of the desktop PC. Groups of data sets can be managed as one.

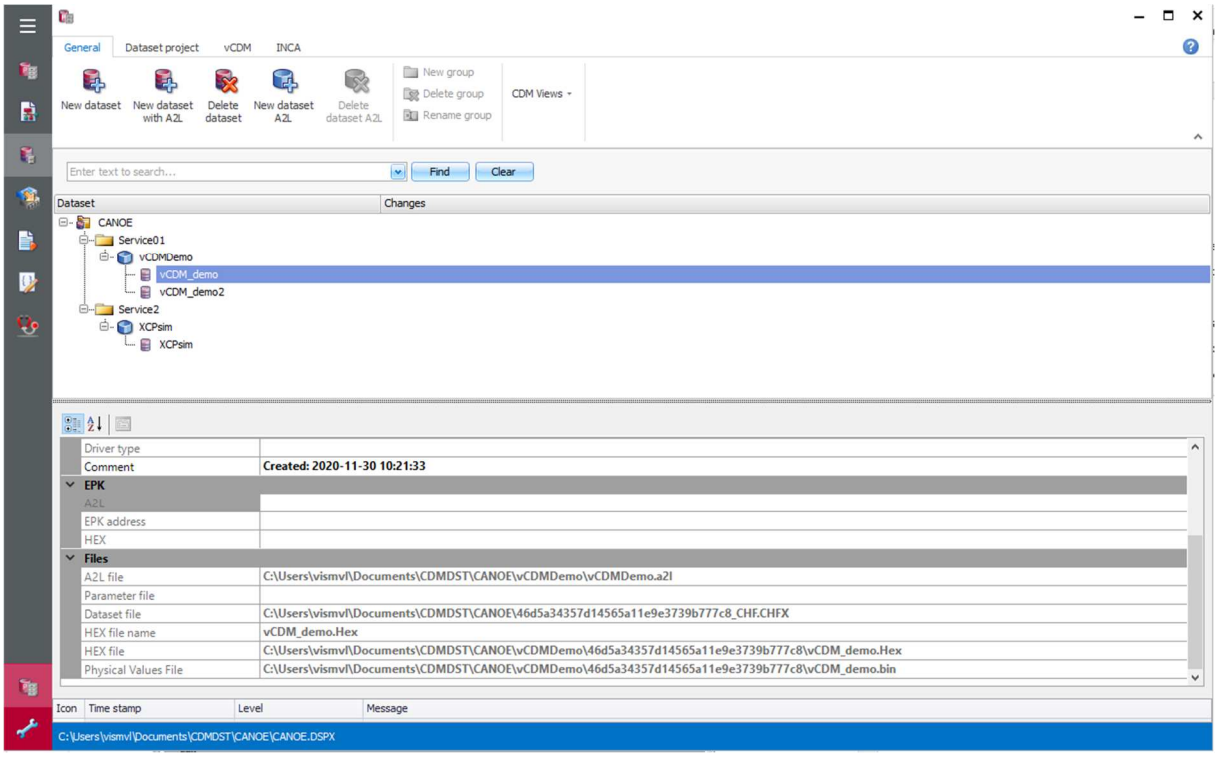


Figure 10: Data set management in vCDMstudio

In large calibration projects many calibrations engineers contribute to the overall result. Local data set management cannot deliver the necessary process support to achieve quality. Multi-user access, parameter permissions and versioning is required. With the product **Option vCDM** it is possible to connect CANape or vCDMstudio to the central vCDM database. Calibration engineers can now deliver quality results. **vCDMcenter** can be used by calibration project managers or data set integrators to create calibration projects and configure the workflow.

2.7 Advantages vCDMstudio

- Easy copy and merge of parameter set files
- Simultaneous comparison of multiple parameter set files
- Filter functions to select parameters for processing
- Supports all commonly used data formats, including CDF 2.0, DCM, Intel hex, Motorola-S, PAR and PaCo
- Saving of parameter set files as M script or code files (in C or hex format)
- Generate various reports, including MS Excel format
- Automation interface for merging, exporting and comparing parameter set files
- Plugin App concept to create your custom applications
- Integrated data set management

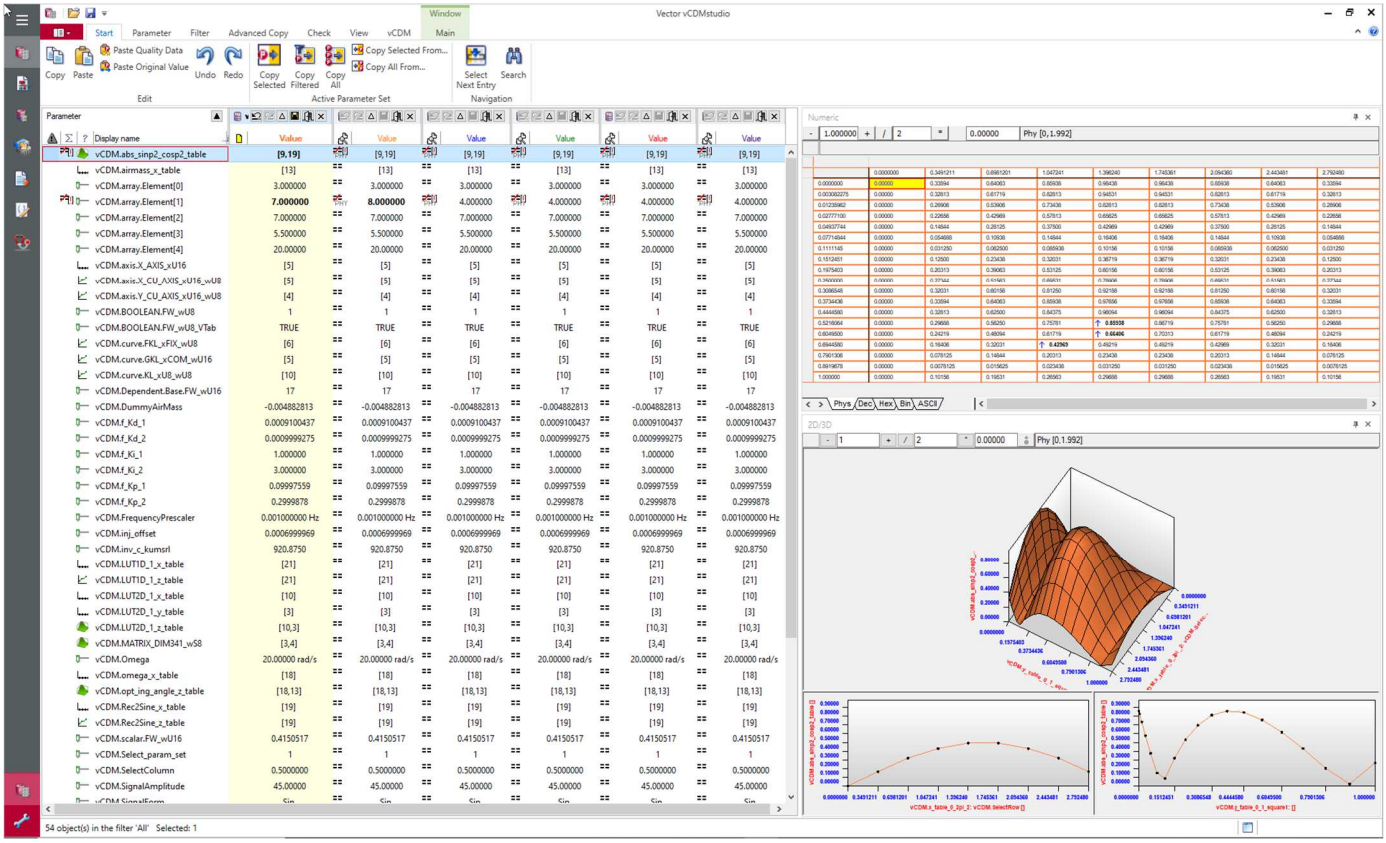


Figure 11: vCDMstudio – Easy like MS Excel, but designed for automotive calibration data

3 Collaboration for success – Option vCDM

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 growing 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 vCDM 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.

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 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.

The vCDM system has specific capabilities when it is used across different automotive domains. 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 calibration data management, it is important to represent the different workflows of the technical departments as closely as possible, instead of prescribing a "standard process".

Figure 12: Collaboration within the team for calibrating ECUs

3.1 Integration of Desktop and Cloud

Users will work with CANape's data set management. Any data sets can easily be shared with other users. Invited colleagues can subsequently download these data sets directly onto CANape.

Changes to parameters can be send to vCDM over the network.

Conflicts which arise from simultaneous changes to the same parameter will be displayed immediately and resolved by the user. You can see who made changes to individual parameters and when.

3.1.1 Sharing Data Sets

The user has created one or several data sets and has perhaps already set parameters. Until now the data has only been saved on the user's PC and now needs to be shared and saved. To do this, the user selects "Share data sets" from the ribbon.

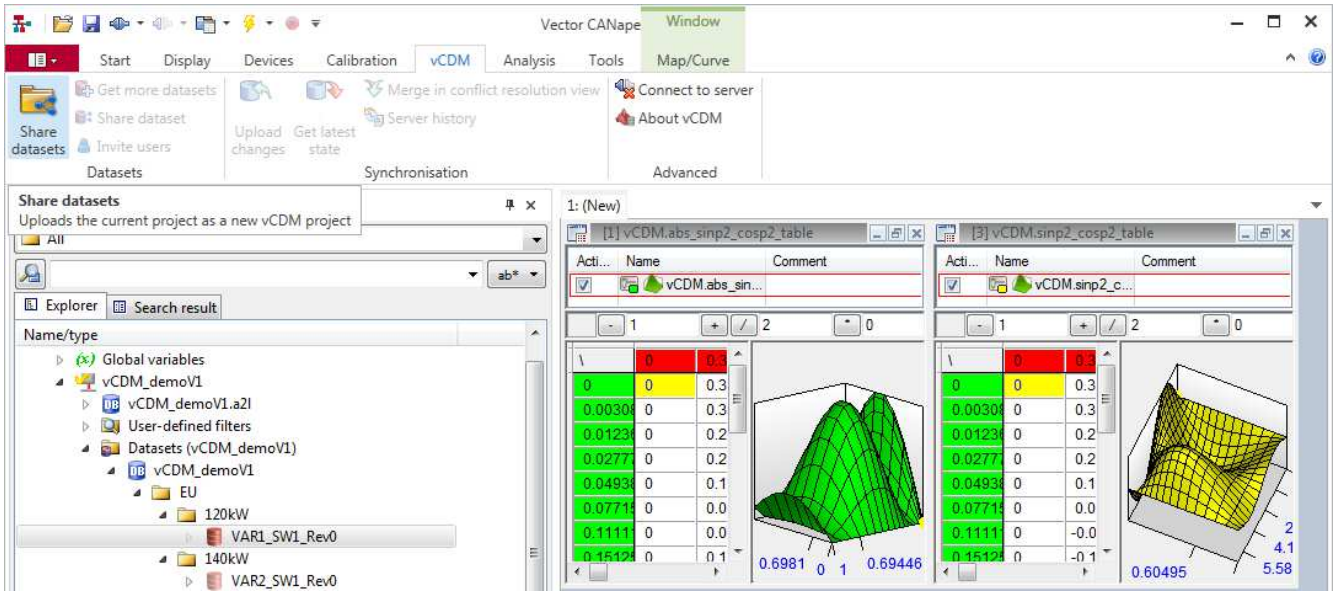


Figure 13: Quick sharing of data directly from the CANape interface

Following this, the data sets and the names of colleagues, with whom data is to be shared, are selected. These data sets are then loaded onto the server and are available to invited colleagues. The server can be in your business network or you can make use of the benefits of the Vector Cloud solution.

Shared data sets are marked with a special icon in CANape. The user can see immediately that the data set is available on their PC as well as on the server.

3.1.2 Loading Data Sets in CANape

CANape users can very easily access shared sets. Instead of manually creating a new record for A2L and HEX files in CANape, with just a few clicks a device can be loaded from the server along with its A2L and data set onto the user's PC and then be made available for editing.

Figure 14: Simple loading of a shared data set in CANape

3.1.3 Exchanging Changed Parameter Values

Data sets that have been shared can be edited by several users. In addition to this, each adjustment procedure can only be seen on your local PC. Your own work results can be transferred to the server by selecting "Upload changes" from the menu. With "View current status" you can load colleagues' latest work results onto your own PC.

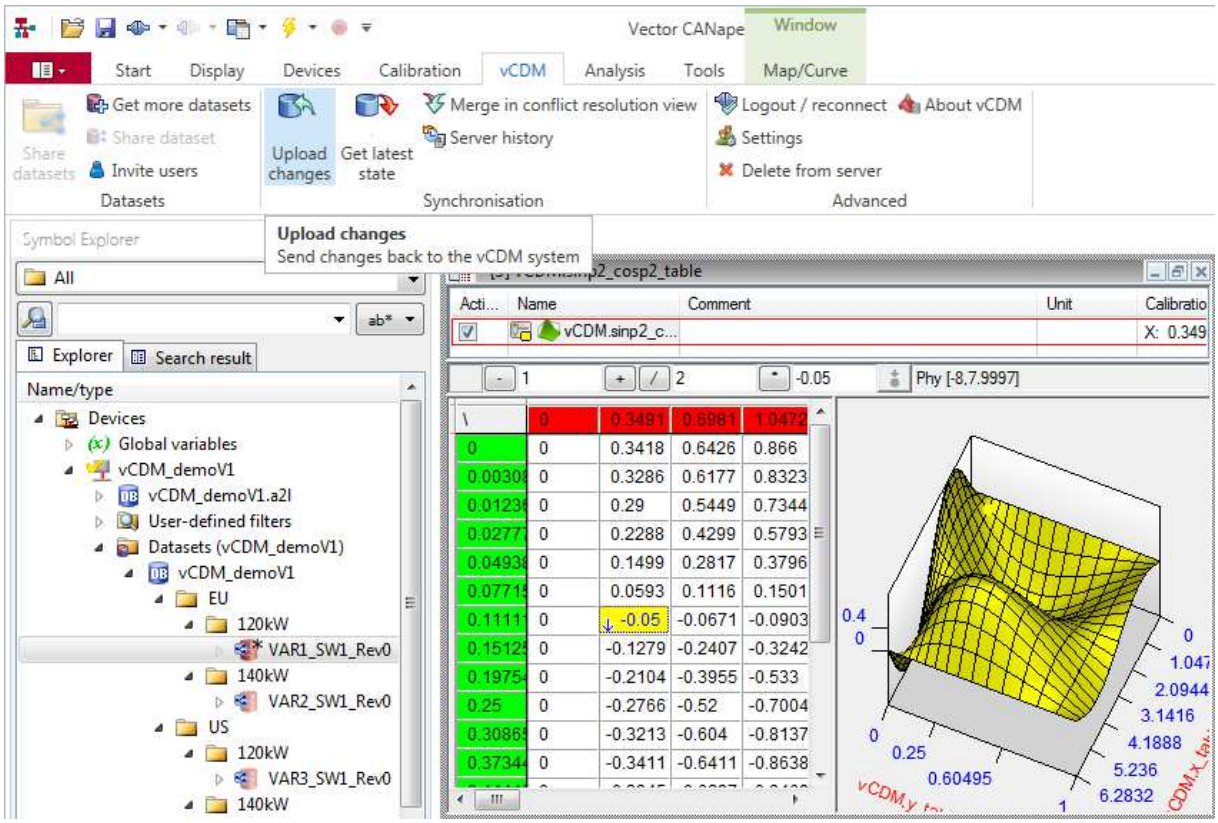


Figure 15: CANape changes and upload changes

3.1.4 Sharing of Parameter Sets

Changes are shared between vCDM projects as parameter set files. These changes are often imported into several vCDM data sets. If work packages are defined in vCDM, CANape not only exports the changed parameters to the exchange file, it also fills the entire work package.

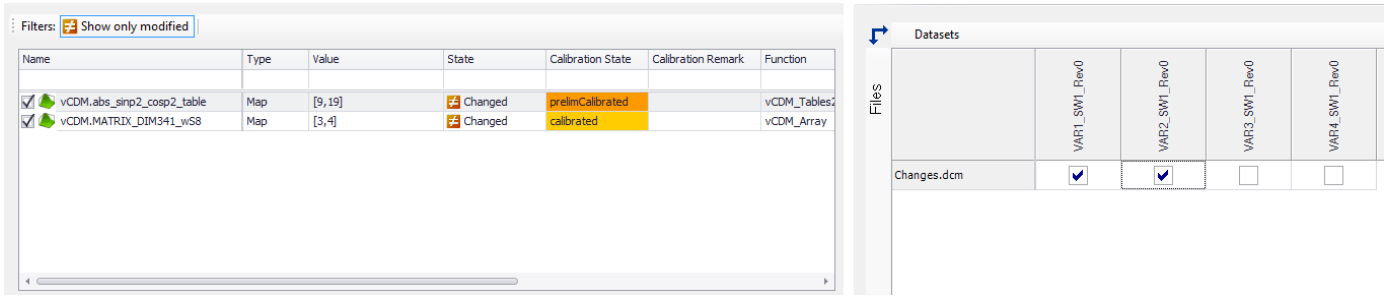


Figure 16: Data exchange by means of files

3.1.5 Handling Parameter Conflicts

If the same parameter is adjusted at the same time, CANape displays a conflict when synchronizing the shared data set. These conflicts can be displayed by selecting "Merge in resolve conflict view" from the menu and can be resolved by selecting the correct value.

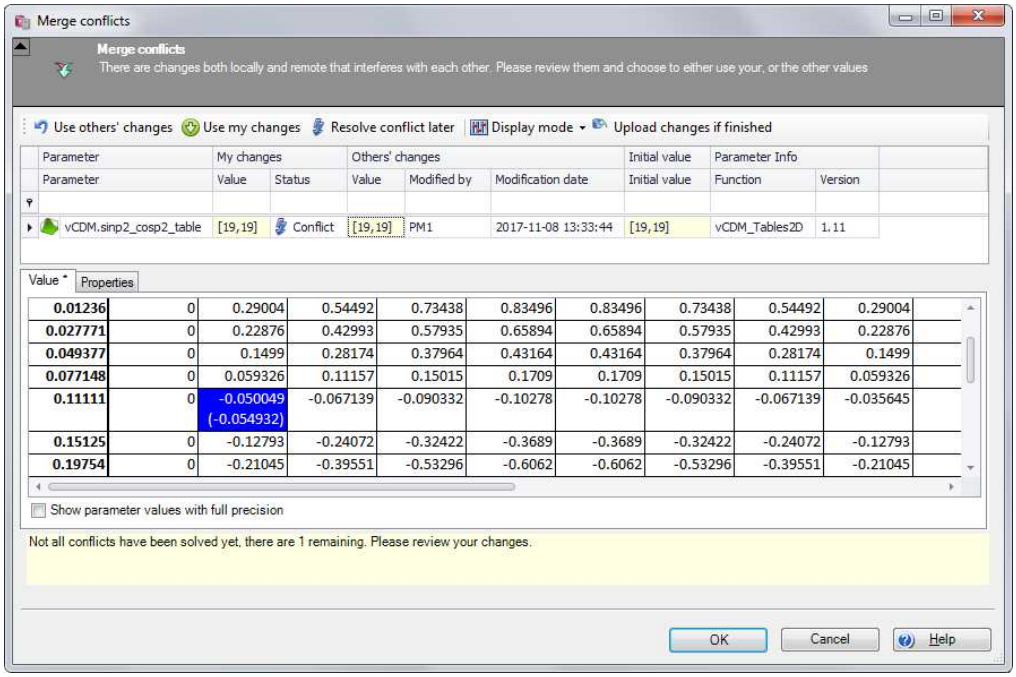


Figure 17: Resolving parameter conflicts is made easy through the clear presentation of different values

3.1.6 Changes History on the Server

The server records any change to a parameter and displays it in the Change History. This means that every team member knows which parameters have been changed by which colleagues and at what time.

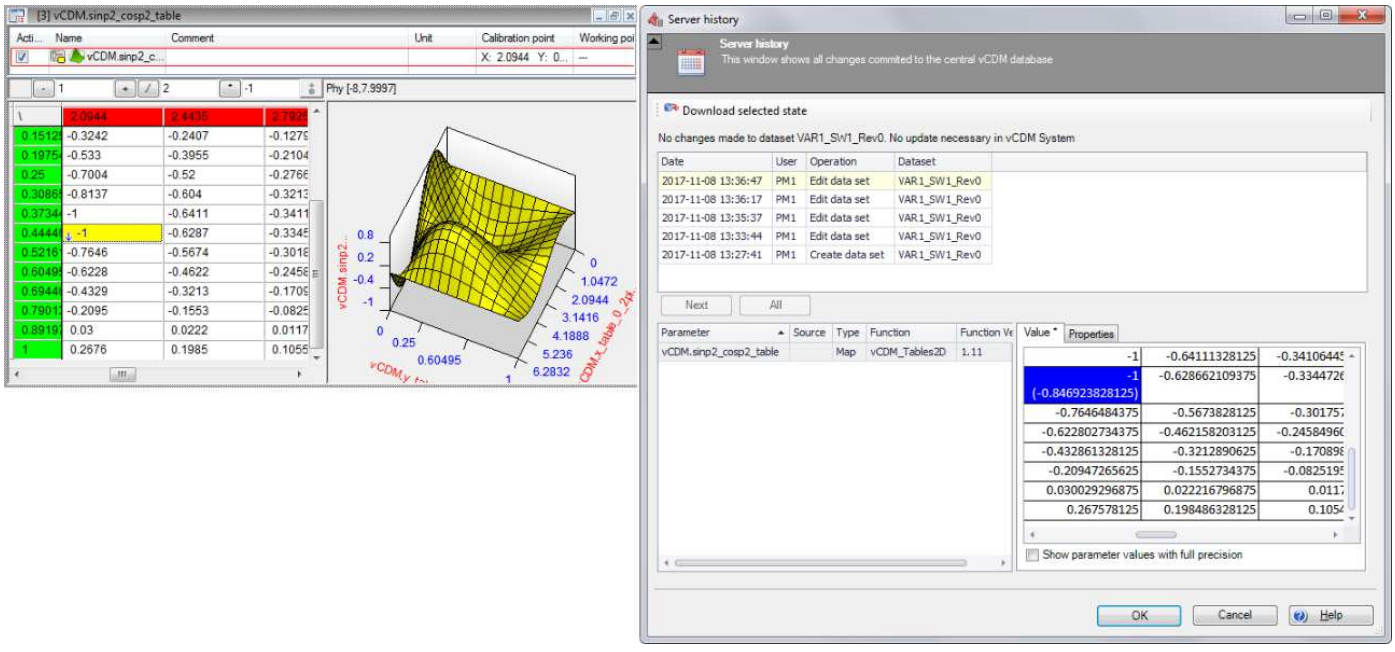


Figure 18: Tracking changes in the Change History

3.1.7 Additional Functions

Calibration engineers are provided with additional useful functions that can be invoked directly from CANape.

- Parameter set files imported into a data set can be displayed in CANape. This also applies to files from other users.
- Attachments can be added to the data set.

- A data set can be written with metadata (attributes)
- Changes can be rolled back
- Calibration progress is displayed in the data set administration
- Parameter set files can be submitted to vCDM Component libraries

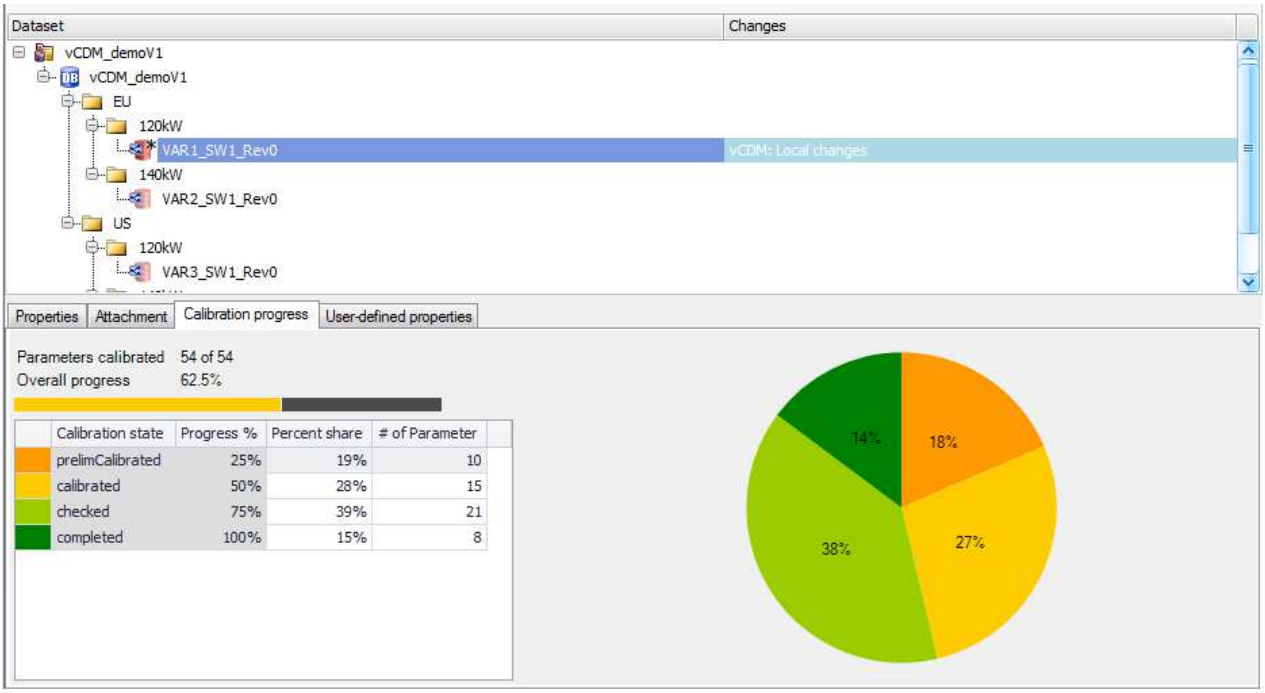


Figure 19: Calibration progress in the data set administration

3.2 Advantages Option vCDM

- Seamless connection from the desktop to the database
- Conflict detection and resolution though the central vCDM Database
- Change tracking and history for parameter values
- Simple sharing of data sets with colleagues – no vCDM dataset manager required
- Easy access to vCDM calibration projects – created by a vCDM dataset manager
- Contribute calibrations to vCDM calibration projects and shared data sets
- High user acceptance by seamless integration with CANape and vCDMstudio

4 Manage and control and the calibration process – vCDMcenter

4.1 Manage calibration projects

vCDM offers an array of functions for managing projects and data variants. These functions are normally executed by a project manager or data integrator:

- **Managing projects and data variants:** vCDM can be used to manage any number of projects. In each project, there may be any number of independent data variants, each of which contains the defined range of parameters.
- **Product properties:** Product properties such as engine displacement, legal emission limits or gearbox properties may be assigned to the data variants. The list of product properties can be supplemented in any desired way.
- **Meta information:** can be used throughout the product to complement calibration data. Some examples are : parameter classifications, additional ECU documentation, software function descriptions

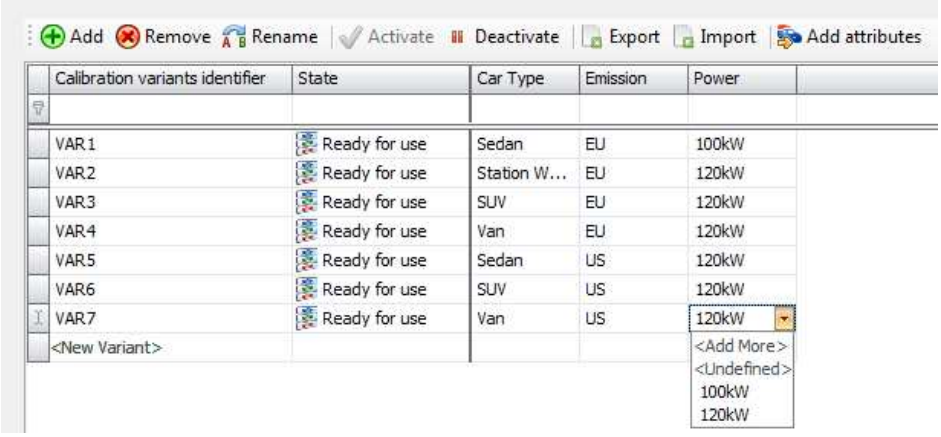


Figure 20: Definition of product properties

- **Structuring of data variants**: Project managers can structure the variants in folders in any way they want. Alternatively, the tree structure can also be calculated from the product properties. These views can be configured to meet user-specific requirements.

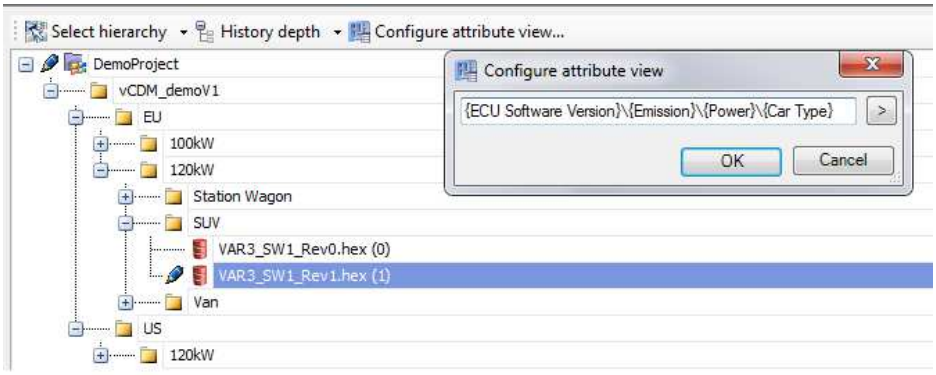


Figure 21: Data set variants grouped in folders

- **Automatic history tracking:** All changes to the data variants are automatically tracked in a history. Development over time and parameter set imports are tracked precisely and can be retrieved later in a few seconds.
- **Defining work packages:** To coordinate the import of calibration data in a team, work packages and rights can be defined. Rights may be assigned in a scaled way – from the project to the variant to the even individual parameter.

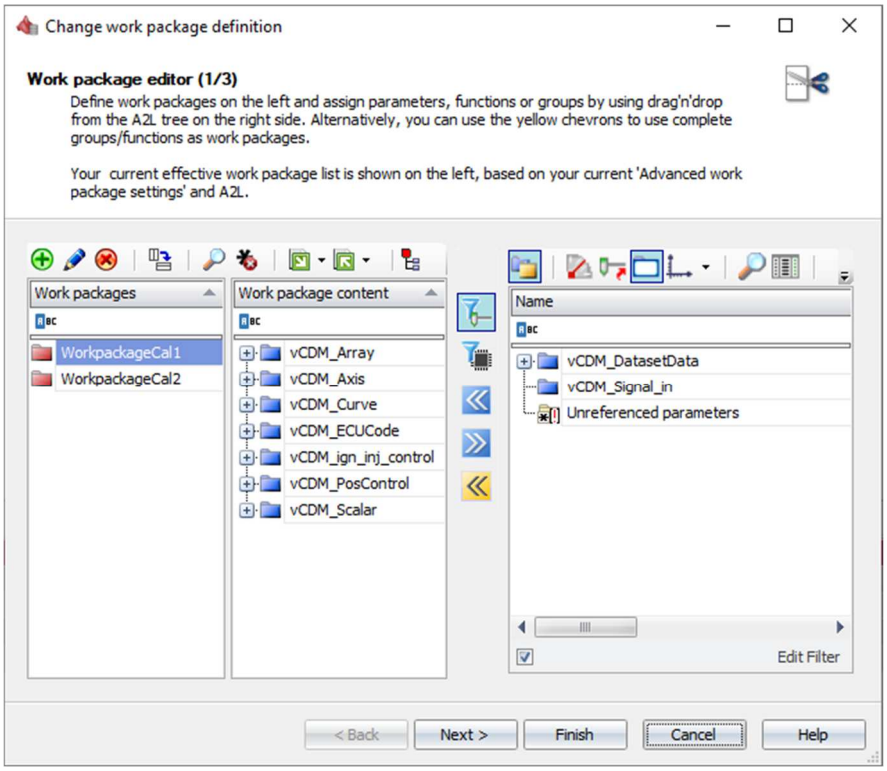


Figure 22: Work packages can be easily defined in the editor

4.1.1 Permissions

Administrators can control the access to vCDM by multiple means and fine-tune what data is available to which users.

Role Management grants or denies access to use-cases in vCDM and permissions control the access to projects and datasets in the database.

Parameter permissions determine which users can change which parameter

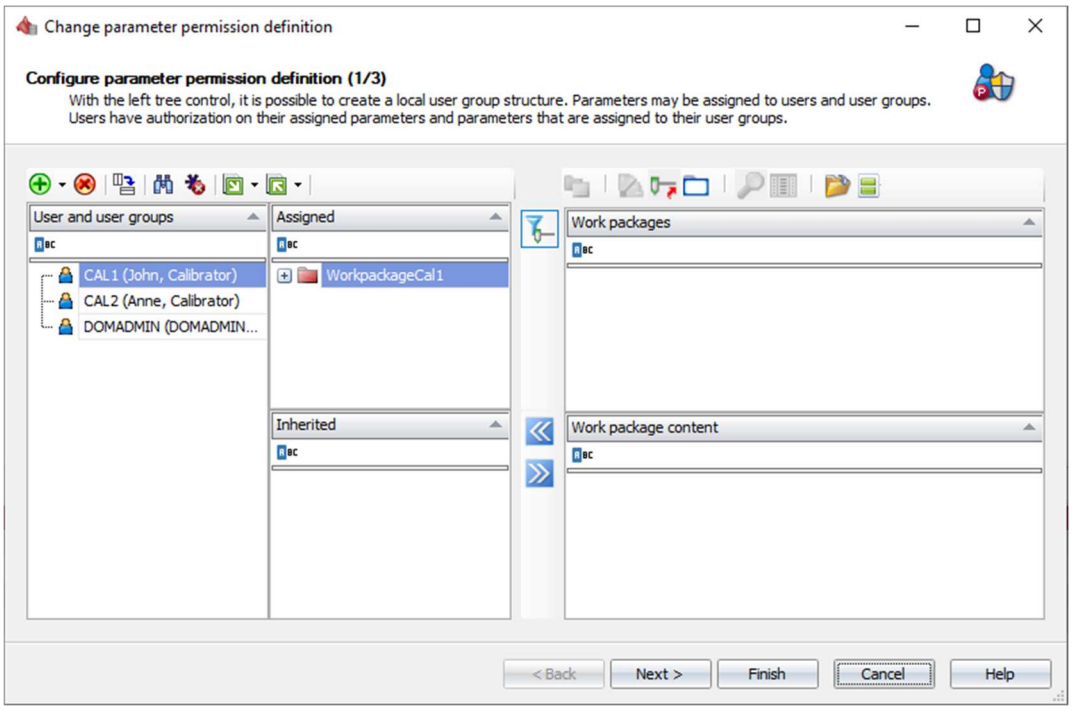


Figure 23: Parameter Permission Editor

4.1.2 Software Changes

When a new software (A2L/Hex) is introduced to a calibration project, the existing calibrations for all affected calibration variants must be migrated to this new software.

- **Optimized for mass operation:** This operation can be executed on many dozens or even hundreds of variants simultaneously.
- **Parameter renaming:** Renaming of parameters is supported.
- **Seamless history:** The software change does not interrupt the history.
- **Parallel work on different software versions:** Even after the software change, older software versions can still be worked on. Software versions are managed as parallel lines of development.
- **Reports:** Differences between A2L files can be exported into a report.
- **Rule based data migration:** vCDM and vCDMstudio feature an integrated wizard which enables suppliers, software developers and experienced calibration engineers to define complex acceptance rules for when parameter properties are changed. These rules are then imported and executed when the software is changed. This enables calibration data to be accepted automatically even when extensive changes are made to the ECU software.
- **Possible scenarios** that can be handled in this way:
  - Unit changes: Automatic conversion of seconds to milliseconds.
  - Parameter type changes: Convert curve to map.

4.1.3 Data management Mode

vCDM supports the different calibration data management modes:

- **A2L/Hex** : The A2L file contains the parameter declaration, and the data is delivered in its binary representation – ready to flash it to the control unit. This mode is typically used for powertrain calibration
- **Hexless:** The A2L file contains the parameter declaration, and the calibration data is managed in its physical representation. Released calibrations can be submitted to a software build process. This mode is typically used for chassis calibration
- **Parameter Editor:** The parameter declaration are entered with an editor or are imported from other tools (i.e. MS Excel) and the calibration data is managed in its physical representation

4.2 Traceability for all calibration changes

vCDM has all necessary capabilities of a version management system. Every dataset and parameter file has its version and lifecycle. Objects can be frozen and branched.

Every change of calibration data sets, parameter files or a single parameter can be tracked.

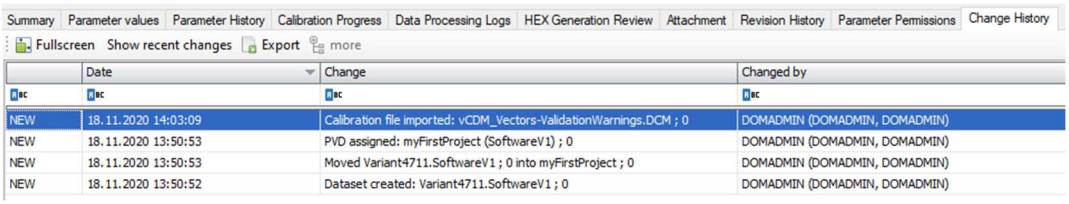


Figure 24: Trace Dataset Changes

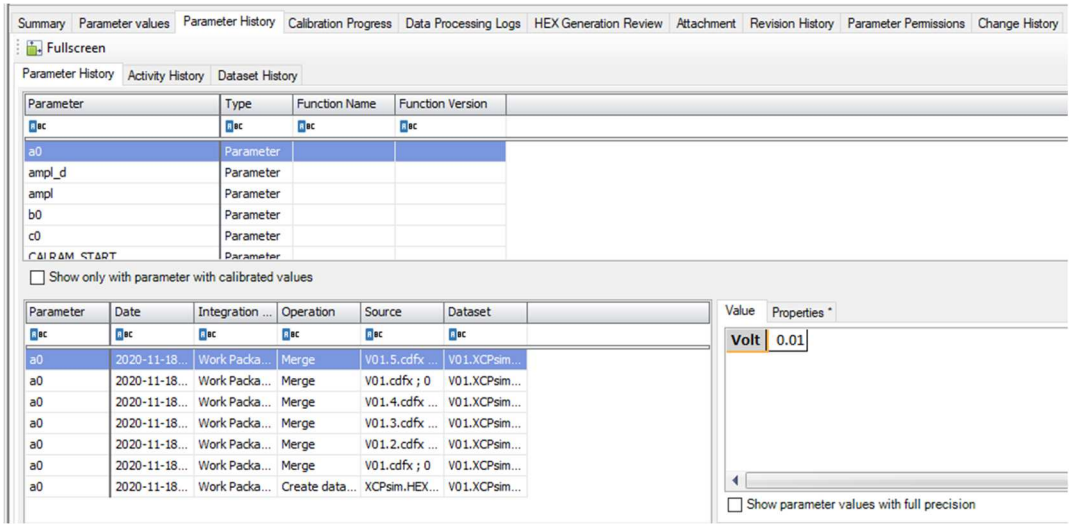


Figure 25: Trace Parameter Changes

4.2.1 Rich Meta model for calibration

Parameters can be loaded from many typical data formats for calibration. Text- or XML-based formats can be processed, as well as binary formats (S19, Hex).

All parameter information is managed in an internal data model. This data model extends ASAM MCD-2MC (A2L) with rich meta information. This enables easy transformation of parameter sources into other formats.

vCDM also supports parameter formats for model-based calibration and software development

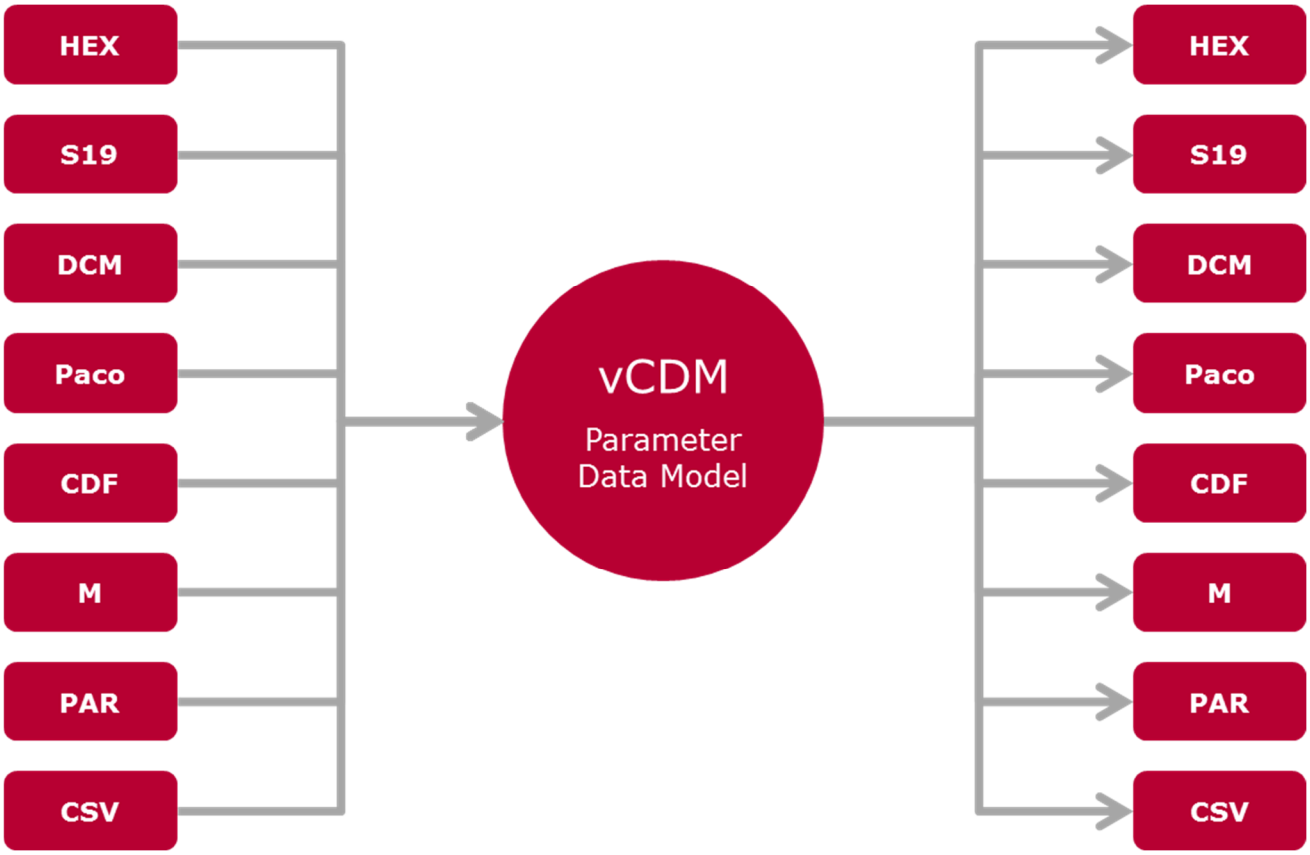


Figure 26: vCDMs internal data model supports easy conversion from and to many formats

4.3 Configure and control process quality

The functions of vCDM support all phases of the calibration process:

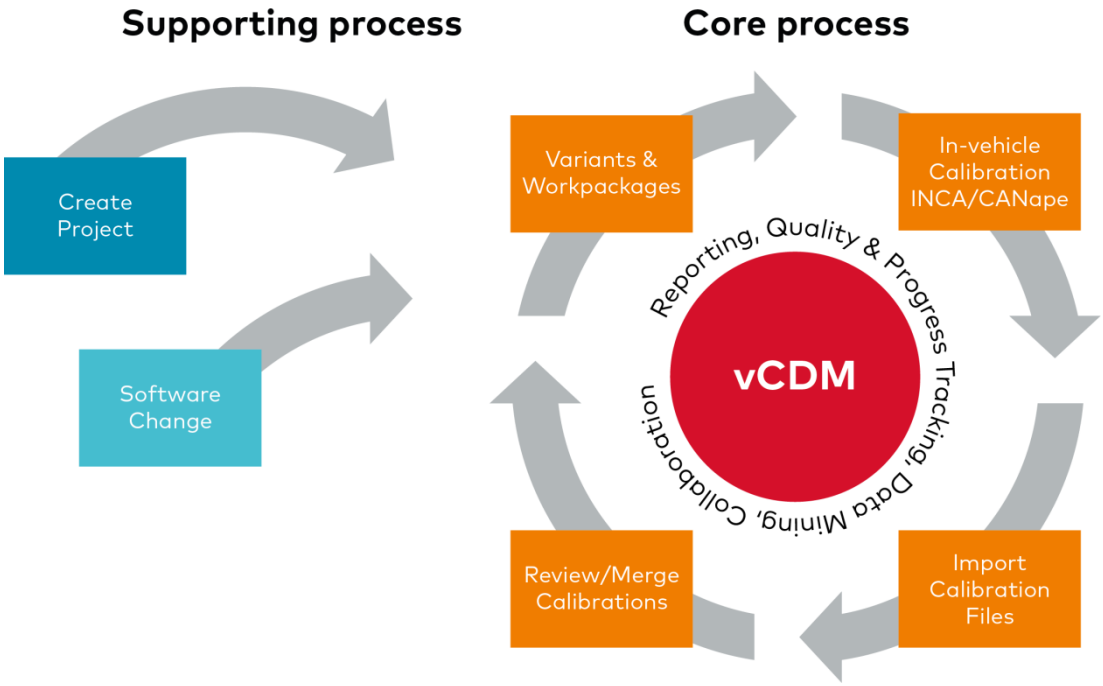


Figure 27: Overview calibration process in vCDM

- Create calibration projects
- Define calibration variants and their attributes (features)
- Set up work packages and permissions
- Import parameter files
- Review changes
- Merge changes
- Detect and resolve conflicts
- Generate updated ECU files
- Transform existing calibration data to new ECU software
- Graphically compare and manually manipulate data with vCDMstudio
- Establish consistency criteria and checks
- Calibration history and overview of incorporated work packages
- Prepare ECU software for production
- Access to all functions via automation interfaces
- Reporting and data mining functions
- Guided mode for new and sporadic users
- Export and import of projects to support test states
- Management of component libraries
- Documentation of calibration expertise
- Special views for special tasks (e.g. OBD blocking behavior)

4.3.1 Import Calibration Data

These actions are performed by the calibrators or data integrators.

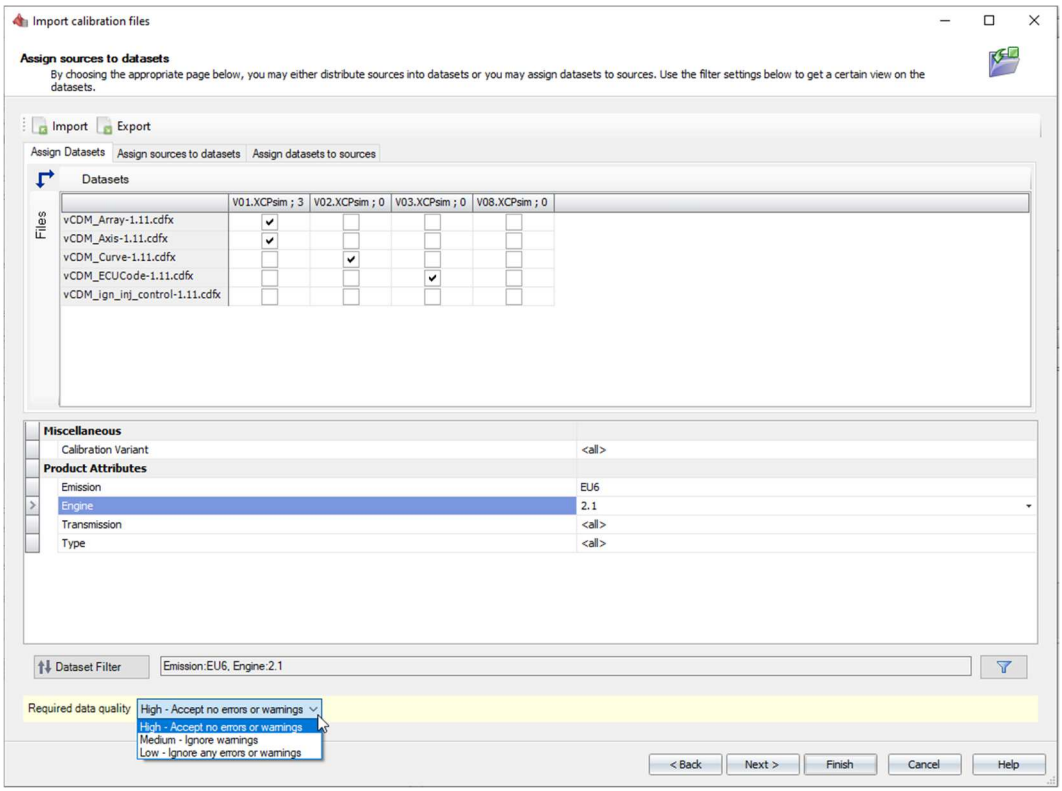


Figure 28: Import wizard for parameter sets

- **Consistency check at parameter set import:** When importing calibration data, consistency conditions such as permissions, work packages, value ranges and other properties are checked.
- **Optimizing for large numbers of variants:** Filters and intuitive user controls help the user to identify all the variants needed for a parameter set import.
- **Merging the data:** Imports by calibration engineers can be conveniently compared and merged. If conflicts occur, they are detected and resolved.
- **Quality data:** When a parameter set is imported, status information and comments can be added and attachments included. It is also possible to link imports to issue tracker and requirements management systems.
- **Optimized user interface:** The complexity of the user interface can be reduced to a minimum for the data import. This lets occasional users quickly learn how to use it.
- **Integration in calibration tools:** A supplemental feature is the direct parameter set import from the CANape and INCA calibration tools.
- **Excel import and export:** Import templates can be exported and reused in Excel.

4.3.2 Merge Calibration Data

These actions are performed by the calibrators or data integrators.

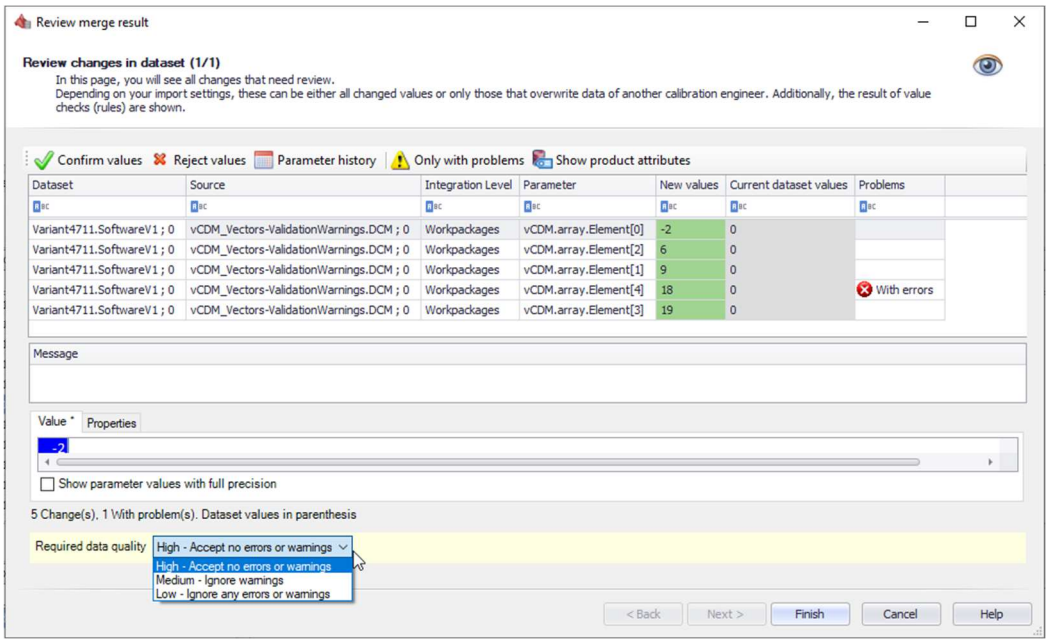


Figure 29: Approval of parameter changes

4.3.3 Generate ECU Files

Once all the necessary calibration data has been imported and merged; the project manager or data integrator generates a new, updated revision of the ECU software:

- **Consistency checks:** Configurable consistency checks are also performed for Intel-HEX and Motorola S-Record generation.
- **Naming rules:** New HEX file names can be generated automatically based on configurable rules.
- **Preparation for production:** The new ECU software can be generated in a form which allows it to flow directly into the production process. Checksums and signatures may be inserted in the ECU file for this purpose (HEX post treatment).

4.3.4 Validation Framework

vCDM provides a validation framework to configure the required data quality for every process step

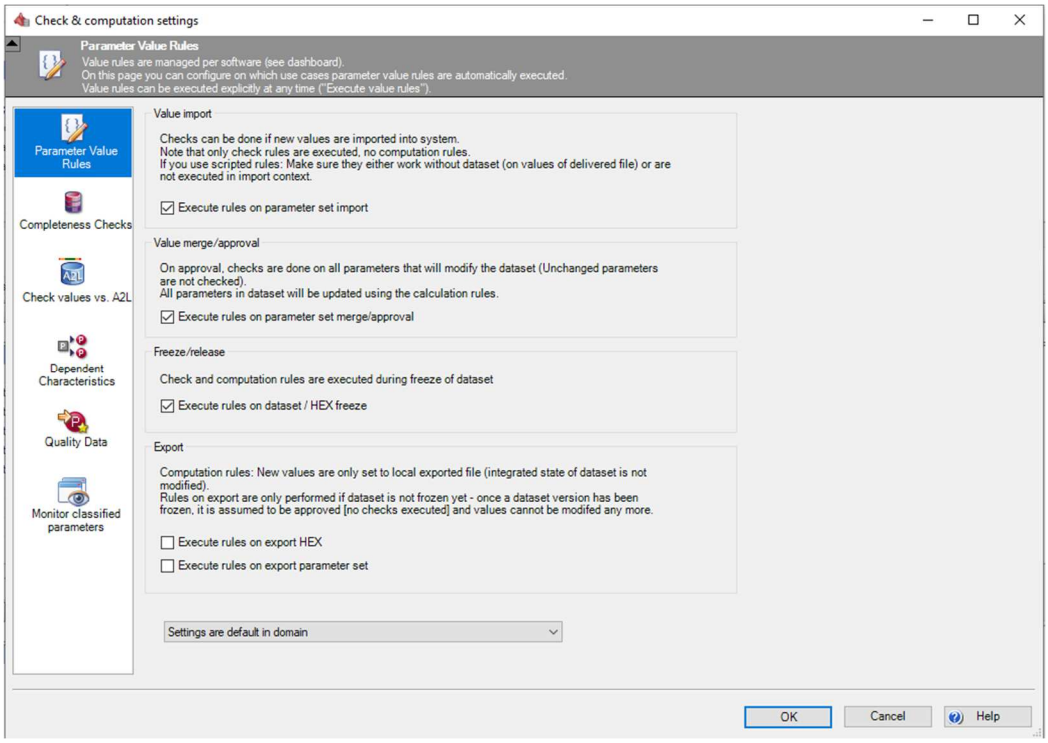


Figure 30: Setup Required Data Quality for the vCDM Validation Framework

4.4 Efficient Management of calibration variants

vCDM offers various methods for keeping a large number of calibration variants consistent. These mechanisms can be applied independently or combined as needed:

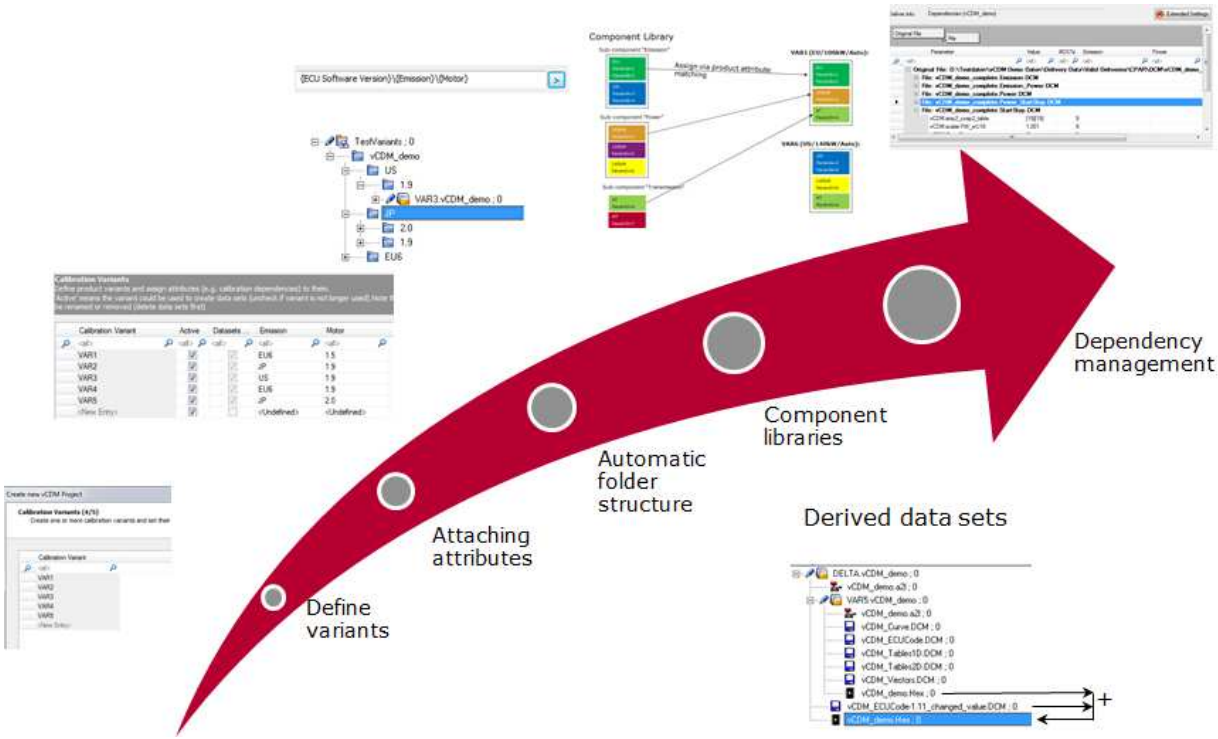


Figure 31: Methods for variant management in vCDM

- **Attribute:** Attributes can be attached to variants to define their semantics more precisely. These attributes are used later on to filter data and for automatic assignment of data from libraries.

- **Calibration matrix:** The calibration matrix clearly presents the available work packages, their instances and where they are used. Work packages can be exchanged from the calibration matrix. Exporting to Excel and the import of changes from Excel are possible.
- **Derived variants:** If there are only minimal differences between variants, this can be handled using derived variants (e.g. test bench versus street test variants). Most parameters in a derived variant originate from the basic variant. Only a small number of parameter values are managed within the derived variant. The values from the basic variant are determined dynamically, and changes are immediately available in the derived variant as well.
- **Component libraries:** Work packages which could serve as a good basis for new variants can be managed in component libraries. Through assignment of the attributes, the libraries can be aligned with the data sets.

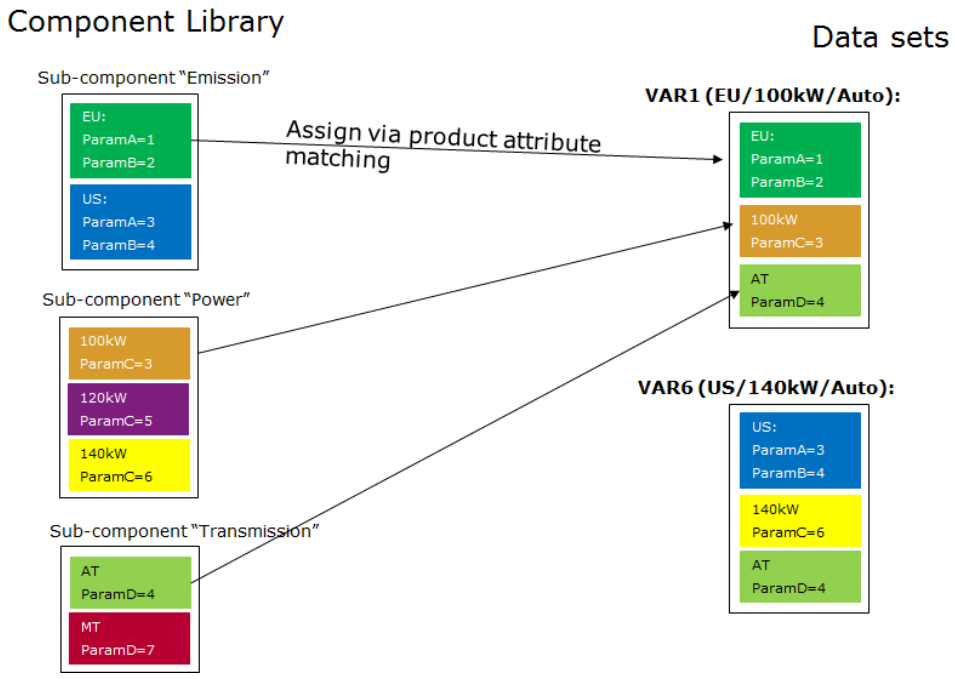


Figure 32: Basic principle of component libraries

- **Dependency management of parameters:** This function is elaborated on in the following chapter.

4.5 Managing Parameter Dependencies

You use this function to manage the dependencies between parameters and variant properties and boost the efficiency of the calibration process:

- **Data distribution to variants:** Data can automatically be distributed to variants. The individual calibration engineer only requires a little knowledge about the structuring of the variants.
- **Consistency check:** Automatic checking of variants for consistency.
- **Automatic filling of variants:** New variants can be pre-filled from ongoing project data to the greatest extent possible. Inconsistent variants are automatically repaired.
- **Calculating dependency relations:** The dependency relations in a project can be calculated by means of a correlation analysis based on existing data. The results are used to configure dependency management and validate new data variants in the light of the dependencies.

4.6 Monitor – Manage – Improve by Analysis and Reporting

vCDM offers an array of reports which can provide important information within a few seconds:

- **Data comparison:** Different variants can be compared to one another. The result can be presented graphically in vCDMstudio and exported as an Excel report. The report includes A2L properties, parameter values, quality information, maturity levels, work packages, permissions and lots more information. A template mechanism can be used for application to different use cases without repeated configuration.

	A	B	C	D	E	F
1	Parameters	DemoProject / VAR3.vCDM_demoV1 ; 1 / vCDM		DemoProject / VAR2.vCDM_demoV1 ; 0 / vCDM_demoV1.a2l		
2		Physical value	Unit	Difference Type	Physical value	Unit
3	vCDM.abs_sinp2_cosp2_table	[9,19]		Value	[9,19]	
4	vCDM.airmass_x_table	[13]	kg	No	[13]	kg
5	vCDM.array.Element[0]	1		No	1	
6	vCDM.array.Element[1]	4		No	4	
7	vCDM.array.Element[2]	7		No	7	
8	vCDM.array.Element[3]	10		No	10	
9	vCDM.array.Element[4]	20		No	20	
10	vCDM.axis.X_AXIS_xU16	[5]	°C	No	[5]	°C
11	vCDM.axis.X_CU_AXIS_xU16_wU8	[5]	Cluster °C(x)	No	[5]	Cluster °C(x)
12	vCDM.axis.Y_CU_AXIS_xU16_wU8	[4]	Cluster Um/p(x)	No	[4]	Cluster Um/p(x)
13	vCDM.BOOLEAN.FW_wU8	1		No	1	
14	vCDM.BOOLEAN.FW_wU8_VTab	TRUE		No	TRUE	
15	vCDM.curve.FKL_xFIX_wU8	[6]	grad C °C(x)	No	[6]	grad C °C(x)
16	vCDM.curve.GKL_xCOM_wU16	[5]	grad C °C(x)	No	[5]	grad C °C(x)
17	vCDM.curve.KL_xU8_wU8	[10]	grad C °C(x)	No	[10]	grad C °C(x)
18	vCDM.Dependent.Base.FW_wU16	17		No	17	
19	vCDM.DummyAirMass	0.0048828125		No	0.0048828125	
20	vCDM.f_Kd_1	0.000999927520751		No	0.000999927520751	
21	vCDM.f_Kd_2	0.000999927520751		No	0.000999927520751	

Figure 33: Map comparison exported to Excel

- **Parameter value instances:** This analysis shows the different values of a parameter occurring in different variants and projects. This analysis can be used to optimize parameters or for a consistency check.

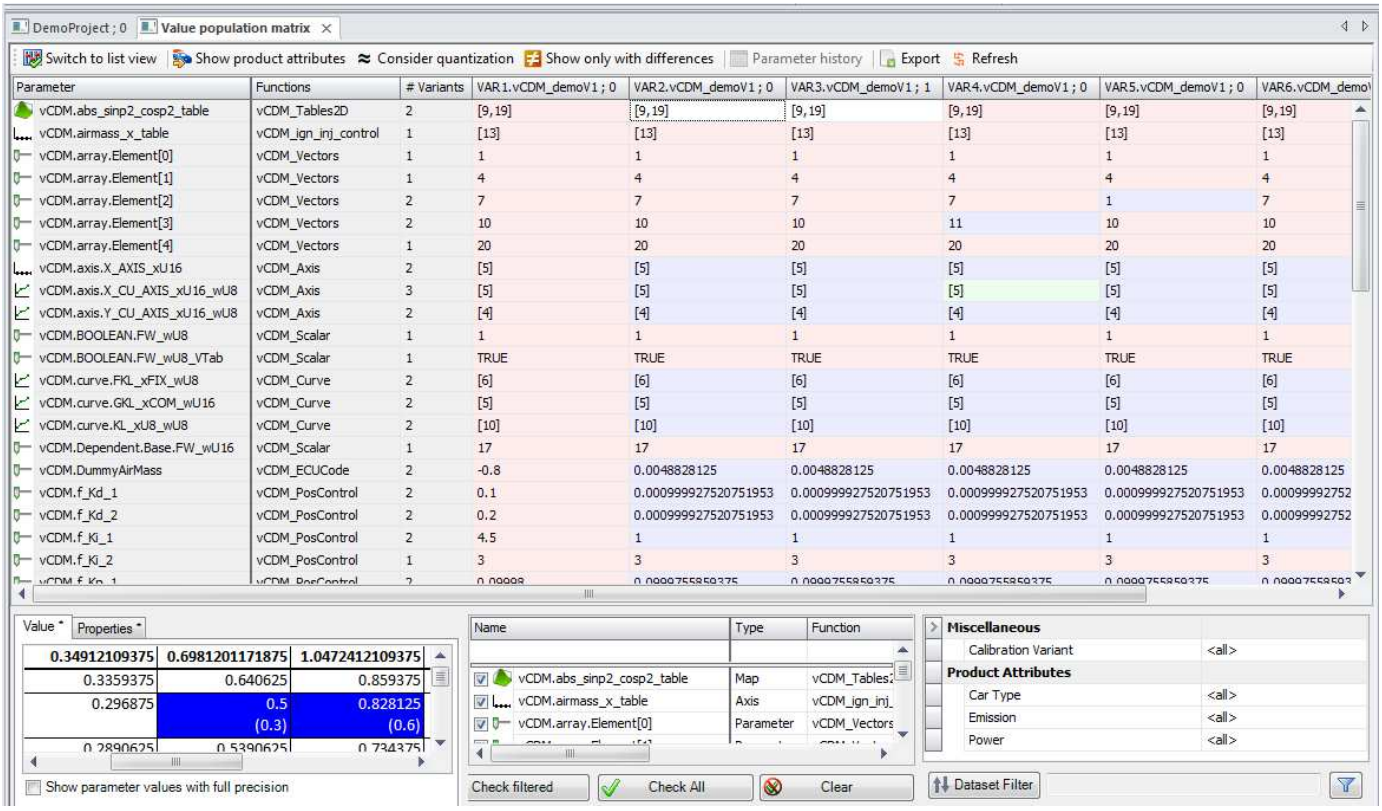


Figure 34: Evaluate occurrences of parameter values in calibration variants

- **Parameter history:** This report answers the question: Who made what change when and from which source? What was the initial value, and to what value was the parameter changed?

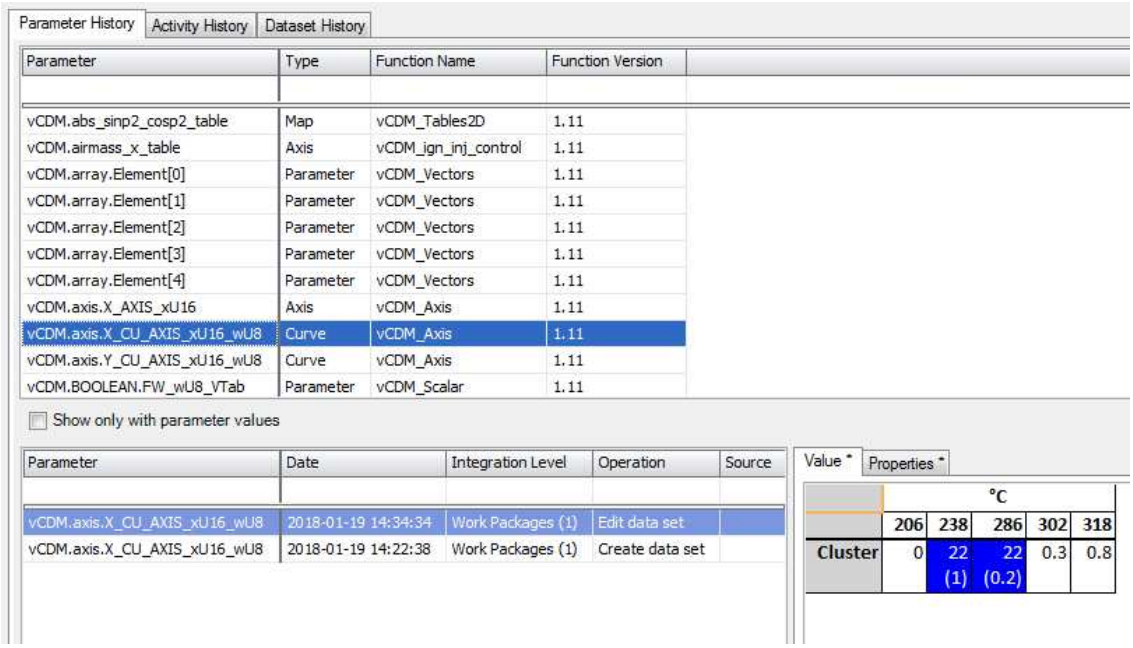


Figure 35: Parameter history

- **List of work imports:** This report provides the sum of imports making up a variant. The history is tracked over as many revision levels as desired.
- **Calibration quality:** The quality of the calibration can be tracked over time or across variants.

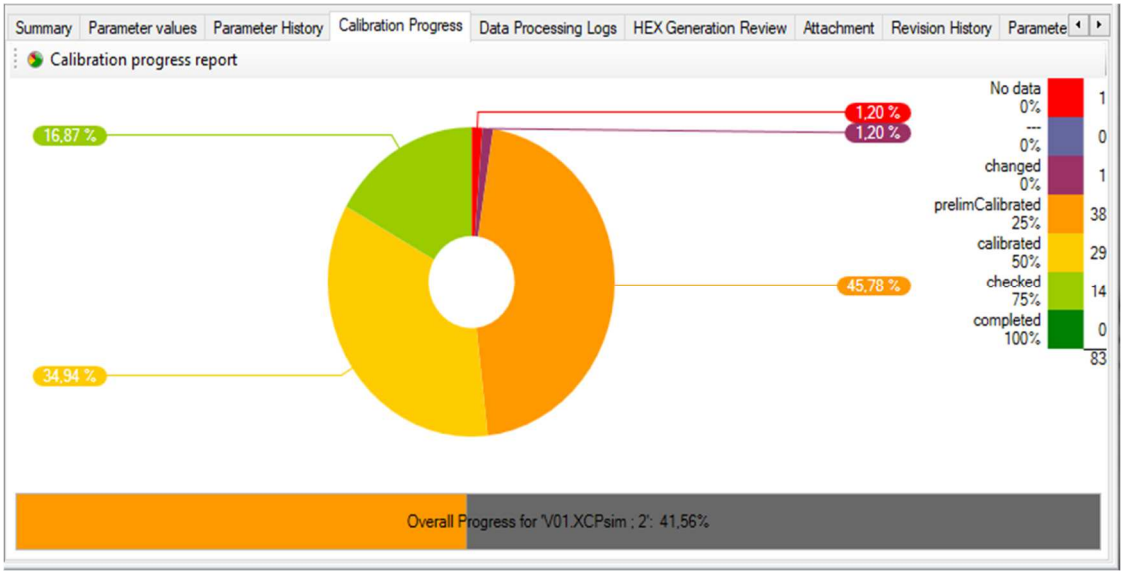


Figure 36: Calibration maturity for data variants

- **Data review with vCDMstudio:** vCDMstudio is used for offline data reviews. By utilizing the filter and search functions, complicated matters can also be responded to. Possible changes can be conveniently merged back into vCDM.

4.7 Advantages vCDMcenter

- vCDM supports the specific requirements of calibration engineers, small teams and globally distributed enterprises.
- The calibration processes and workflows can be adapted to the size of the company.
- All changes to the data can be traced without interruption.
- All operations are optimized for a wide range of variants.
- vCDM can be used for different ECU architectures (AUTOSAR, Adaptive) and calibration concepts.
- Domain-specific views visualize certain aspects of the calibration data in a clearly structured way.
- vCDM is integrated with the CANape calibration tool.
- vCDM ensures consistent data quality for calibration variants
- Extensive programming interfaces (APIs) are available.

5 Easy access to the vCDM Database – vCDMweb

vCDMweb is easily accessible with a standard internet browser. It offers a selected set of functions to distribute calibration knowledge throughout the enterprise.

- Search and Download of released calibration datasets
- Reports on calibration progress and maturity
- Upload of new ECU software

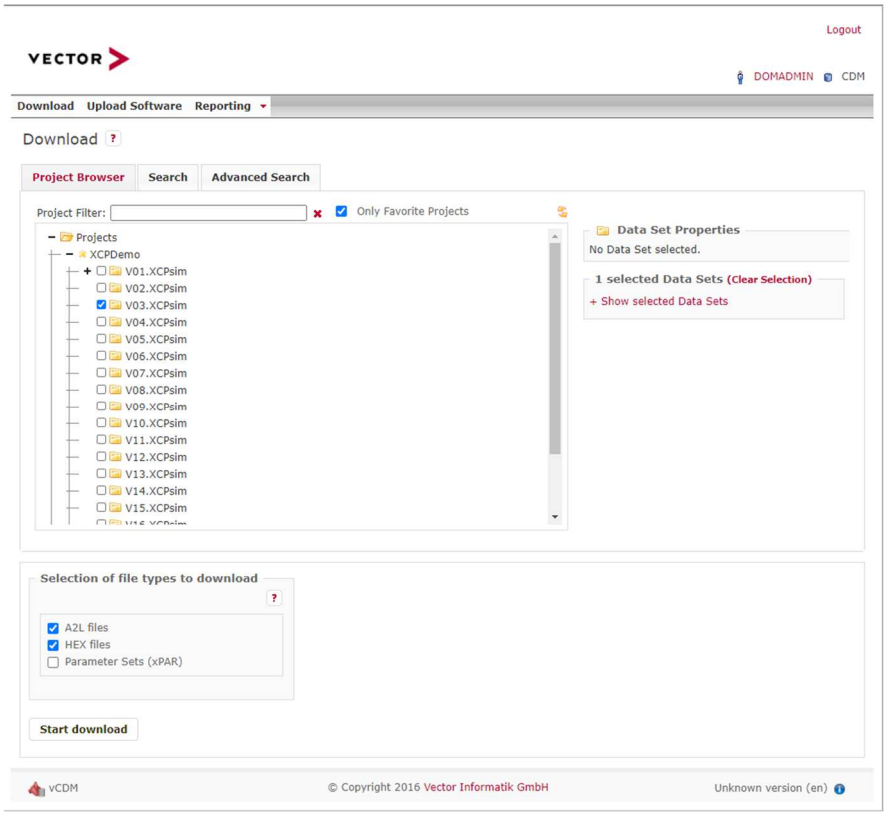


Figure 37: vCDMweb

5.1 Advantages vCDMweb

- Cost-efficient distribution of calibration knowledge throughout the enterprise
- Access-control by roles

6 A software architecture for today and tomorrow

6.1 Cloud-ready 3-Tier architecture

vCDM system architecture introduces clear and distinct layers. The client applications vCDMcenter, vCDMweb and Option vCDM with CANape or vCDMstudio connect to the data center with internet protocols. The data transfer is optimized for global deployments and poor bandwidth.

The business logic is provided with the vCDM server in a secure datacenter – on-premise or in the cloud.

Opensource MariaDB or Oracle DB can be used as database server. The Repository server stores all files and multiple instances can be setup for global replications.

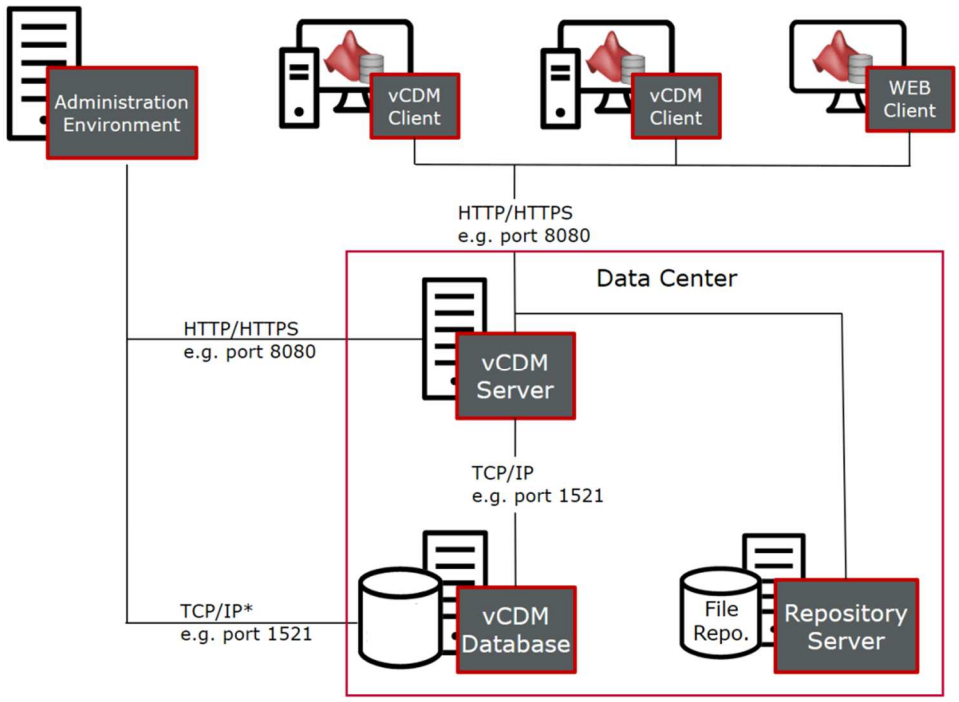


Figure 38: vCDM 3-Tier architecture

6.2 Cloud-based vCDM - Software as a Service

The vCDM Software-as-a-service (SaaS) is a cloud-based solution. It offers considerable benefits for business users:

- No need for dedicated hardware resources
- No investment budget is needed
- Best-practice server operation by Vector
- Cost-effective operation
- Faster provision (cloud system is ready to use in a very short time)

The entire infrastructure for operating the server will be provided by Vector and its service partners. A high level of data security is guaranteed through security measures (encryption, client separation, ISO 27001 certification). Selected, globally distributed computing centers ensure fast response times.

All costs for hardware, software and databases are included in the subscription fee. There are three different levels of configuration. Our service level agreements offer 99.0% availability and 2 hour recovery.

Vector Cloud Configuration Levels

Level of Configuration	Small	Medium	Large
Max. number of users	30	200	>200

CPUs	4	8	16
Memory	4 GB	8 GB	16 GB
Hard disk space	65 GB	250 GB	2500 GB
Data transfer	8 GB per month	30 GB per month	240 GB per month

Table 1: Sizing of server components for several service levels

6.3 Open Source

vCDM supports the open-source web application server TOMCAT and open-source database MariaDB. This enables cost-efficient installation and management for the backend server.

6.4 Microsoft Azure

Microsoft Azure is a cloud computing service created by Microsoft for building, testing, deploying, and managing applications and services through Microsoft-managed data centers.

vCDM can be deployed on Microsoft Azure.

7 Training Classes

As part of our training program, we offer various training courses and workshops on vCDM at our classrooms in Stuttgart and locally at our customers' locations, or online

You can find more information on individual training classes and dates at: www.vector-academy.com

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