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Integrated, model based development of the E/E-system of a new vehicle platform for all future cars of CHERY

1. Short form

This paper reports about the integrated, model based development of the E/E-system of the new vehicle platform of the automotive OEM CHERY in China. The goal of the 3.0 product matrix is the positioning of CHERY on eye level with european luxury brands, with features known from BMW and Daimler. The new cars shall be the best choice for the „young urban professional“. The new flagship M31T built on the new platform is shown at the IAA Frankfurt 2017.

In order to achieve such a quantum leap CHERY founded the CTCS (Chery Technical Center Shanghai). The Management-Team got filled with highly experienced international leaders from automotive OEMs from e.g. the United States of America, Germany and France.

The management faced an enormous challenge: rising the Center, building the organization, infrastructure, engage the right people in a difficult market with 25% fluctuation per year and form the teams. Thus the well understood problems with huge, complex engineering processes at the OEM's of the „old world“ should be avoided. Small, agile teams with a high level of responsibility for the process and the product can change the game by focusing on innovation instead of documentation.

Starting in 2014 a small team of engineers of CHERY und 3E-motion created a completely model based, integrated engineering process for the development of the E/E-system platform. This process uses traditional development methods („Excel-engineering“) for Rapid Data Creation on one hand and integrates all subsystems and domains via a XML-based, open Vehicle Reference Model. All the domain specific views on the data as well as the specification documents and data for suppliers is generated from the reference model. The CTCS-team introduced a paradigm change: from error prone, time consuming interface management based on documents to data based engineering with consistency control by integration.

Once the big step to data based engineering is done, the benefits of such a method are a tremendous reduction of development time and effort by Engineering Task Automation, reuse of proven solutions and the elimination of faults by algorithms controlling consistency and plausibility of the data. Examples are the automatic generation of all dbc-files for the CAN communication of the whole car from a communication model, the automatic generation of the documentation and the automatic generation of wiring diagrams from the electrical master-model.

The tooling provided by 3E-motion enabled the team to generate most of the models automatically from simple Excel-sheets. The introduction of the fully model based, integrated engineering process follows the three steps Transformation, Integration and Automation.

This paper presents the E/E-engineering process using examples from the vehicle platform development like system architecture design, function specification and real time communication.

2. Motivation

In 2013 the biggest Chinese car manufacturer CHERY (>5 million cars sold) decided to place it's brand at least one level higher in customer's perception. With it's participation in QOROS CHERY already proved, that China can develop cars on eye level with the big European brands[1].

China is on the move and going to take world wide leadership in many respects. Consequently the next generation car platform of CHERY addresses the „Young Urban Professionals", who build the new China courageously with great commitment and willingness to change. The result of this generation's work is impossible to ignore, especially in Shanghai. Ultra-Highspeed Internet even in the Underground, a single electronic ticket for Metro, Bus, Taxi, railway and ferry boat as well as hundreds of thousands of electric scooters which starts at 200€. The smart phone is used to pay at the family mart, chat with the taxi driver and open the lock of rental bikes.

The only constant there is change, especially on the automotive industry. Cars connected to the city's infrastructure, new services which require access to the real time data of all cars and autonomous driving have severe impact on the structure of the vehicle's control systems.

Switching to electric powertrains changes the system architectures dramatically due to the elimination of fuel powered engines, gear boxes, exhaust and engine cooling system, oil and AdBlue fluids and all the associated sensors and actuators. In order to master all this challenges CHERY decided to develop a whole new system architecture for it's new vehicle platform.

3. Organization

Organizations that have been developed and optimized over decades are not easy to change as can actually be seen in the European automotive industry. The technical platforms have been optimized for production, to be able to build as many variants and derivates as possible on the same production line with just a small number of differences.

The elimination of complete systems like the powertrain with engine, gearbox and all the auxiliaries is not an option. The departments developing the traditional powertrain face the jeopardy of their existence and react with demarcation and „Information hiding" to resist change. The suppliers in the delivery chain are affected even more because their products get obsolete.

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[1] Euro NCAP awarded the Qoros 3 "Small Family Car" Best in Class for 2013, and was recognized as the best of all 33 cars tested in 2013.

Likewise on component level also the IT-departments cooperate with just a few big vendors of software tools. Innovation and change can endanger the smooth operation of the running process and is avoided if possible. Bad experiences in big improvement projects with vendors who promised process integration but couldn't meet the goals despite investments of more than 100 million Euro are forcing a very cautious approach in process changes.

In order to avoid these traps and pitfalls CHERY decided for a „green field approach" and founded a new Technical Center, similar to the i-Project of BMW. Consequently this center is located in Shanghai, close to the target customers. The top level management of the CTCS (Chery Technical Center Shanghai) was filled with experienced international managers from many countries like USA, Germany and France. On the second level Chinese managers with international automotive background started to build the teams. As the staff evolved and moved throughout the organization, engineers became managers and managers became leaders.

4. E/E-Team

As the head of the Electronics/Electrics area Joerg Brandscheid[2] was put in charge. He held the same position at CLAAS before. As partner for the E/E system architecture design and process integration 3E-motion was chosen. Under the lead of Brandscheid a 3E-team already built reference models of all vehicles at CLAAS like harvesters, field choppers and tractors and developed a new system architecture approach for connected vehicles based on EtherCAT.

A modern harvester is an automatic guided vehicle, which is controlled by lasers, cameras and satellite maps. The harvester controls tractors remote to be able to unload the grain into the trailer of the tractor. The driver controls the process by touch screens and joysticks. All the data is sent remote to a farm management system and data base. Thus the feasibility of a completely integrated, model based engineering process which fulfills the future needs of the automotive industry was proven.

The E/E-team of the CTCS consists of the areas system architecture, system design, electrics, diagnosis and HMI, complemented by experts of 3E-motion on site. These experts supported the development of the model based process and methodology and delivered both the modelling and the transformation tools.

5. Process

Engineering processes in the automotive industry today are determined by the split of tasks into many small packages, so-called subsystems. This strategy leads to a lot of interfaces which exceed not only technical boundaries but also the borders of organizations and companies. Sensor fusion, connectivity and distribution of functions forced even more interfaces which created massive problems in the development of E/E-Systems, resulting in a high degree of insecurity and frustration on customer side.

As a consequence the development of integrated, model based engineering systems managing the whole vehicle data was started. OEMs invested hundreds of millions in projects integrating thousands of engineers, targeting savings of 1 billion Euro per year but all existing modelling techniques and tools failed in the modelling of a whole car control system platform.

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[2] Today Joerg Brandscheid is head of the powertrain division of Continental

The focus was therefor put on the optimization of the interface management to master the exploding complexity of systems and processes utilizing „Requirements Management".

Unfortunately the pressure on engineers increases as much as the complexity, development time schedules get tougher, there is no time for a complete and professional specification of what should be done before starting the implementation. In consequence people work with local data ("E/E" = "Excel-Engineering") and transfer it later on into the „official" IT-systems. Thus a kind of „parallel world" developed where a new class of experts work on the evaluation of „Maturity" and „Stability" of requirements instead of thinking about solutions.

All this thwarts the efforts of cost reduction and impedes the acceleration of innovation and change in today's world of monthly updates.

The E/E-management at the CTCS was very well aware of these problems. Instead of employing thousands of engineers a complete new process was developed, supporting small, highly flexible teams of experts. This process integrates all the participants as well as the complete data based on a reference model of the complete vehicle.

This reference model keeps all the data of the E/E-system and provides the change from error prone, document based process to data based system engineering.

Subsystems and interfaces are generated from the reference model and checked for consistency. Documents are generated automatically from the models. Once the data is available in the reference model the last and most important phase of the process implementation started, the automation of engineering tasks. Whenever possible data, documents and wiring diagrams are generated automatically, thus eliminating errors, corrections and iteration cycles.

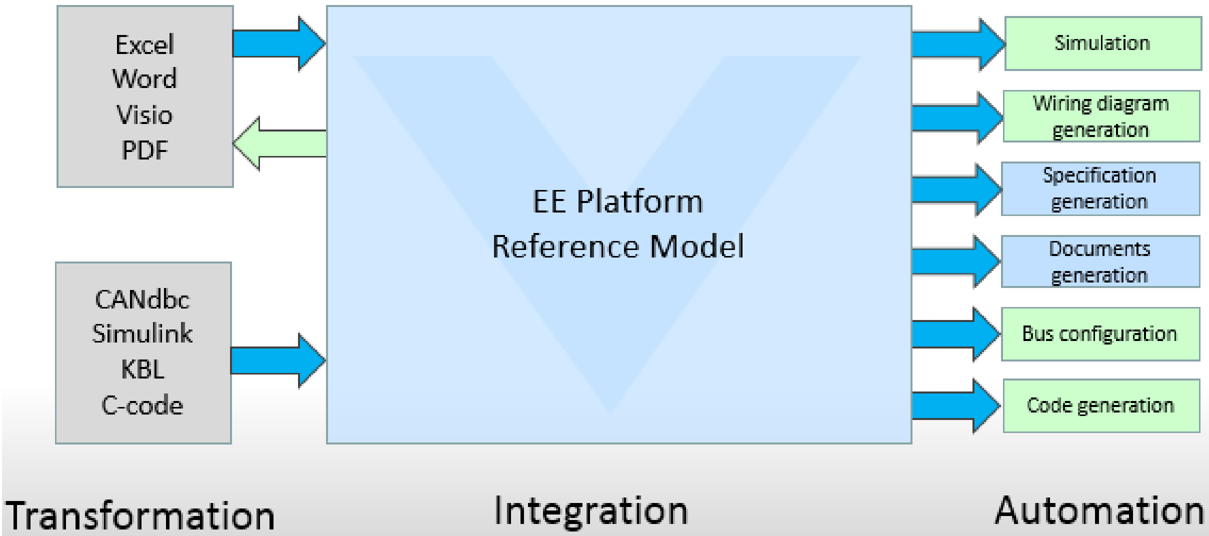

Figure 1: Transition from document based process to automation of engineering tasks

The often unjustly attacked „Excel-Engineering" is integral part of this new process, used for „Rapid Data Creation". All team members can use Excel, even in team meetings. 3E-tools transform the Excel-sheets into models. These tools can be adapted ad hoc and transform data from e.g. Excel, CANdb, Simulink or other tools into XML. The product reference model uses XML as description language based on an open, readable data schema. After transformation the data is integrated into the reference model and thus represents the product. Excel-sheets, simulation models, documents or wiring diagrams can be generated again from the reference model.

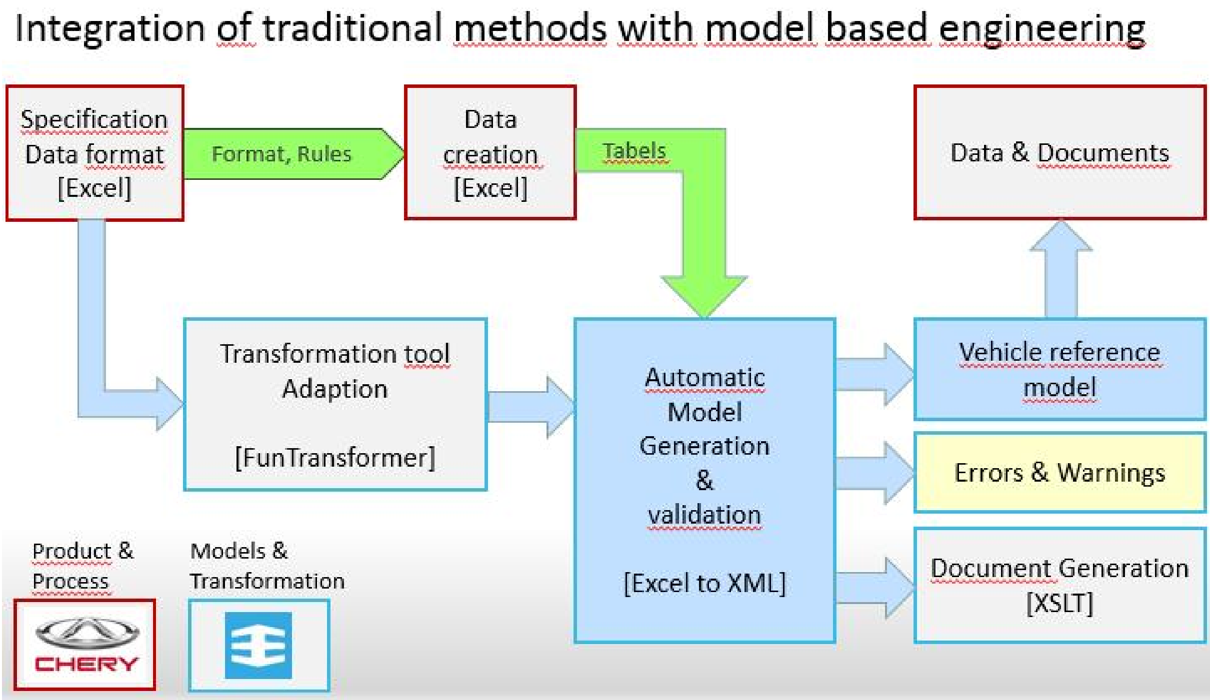

Figure 2: Cooperation of teams in the design and implementation of process, methodology and tools

Even the software can be created within the reference model. Using integrated, model based development environments like RAPTOR/Simulink the production code of the ECUs can be generated, taking variants and options into account. One of the benefits of this methodology is the access to data of vehicles driving anywhere in the world via TCP/IP. In this case the real time values are represented directly in the function model, without the need to know on which ECU the software is running and how to connect to this ECU. It is even possible to “Force” (override) the original values in the car temporarily for remote diagnosis and maintenance. Future traffic control systems for autonomous vehicles will demand such functionality to be able to stop vehicles which behave in a strange manner.

During the development of the vehicle platform not only the models have been developed, but also libraries for each domain. These libraries are generic to a big extend and deliver well-engineered solutions and implementations for each aspect of the E/E-system including features, requirements, functions, architectures and even software code. Together with engineering task automation these libraries cut down time, effort and risk in the development of future vehicle developments tremendously.

6. Methodology

The whole vehicle reference model with all it’s aspects is created fully graphically. This includes all information which today is specified as text only like features or requirements.

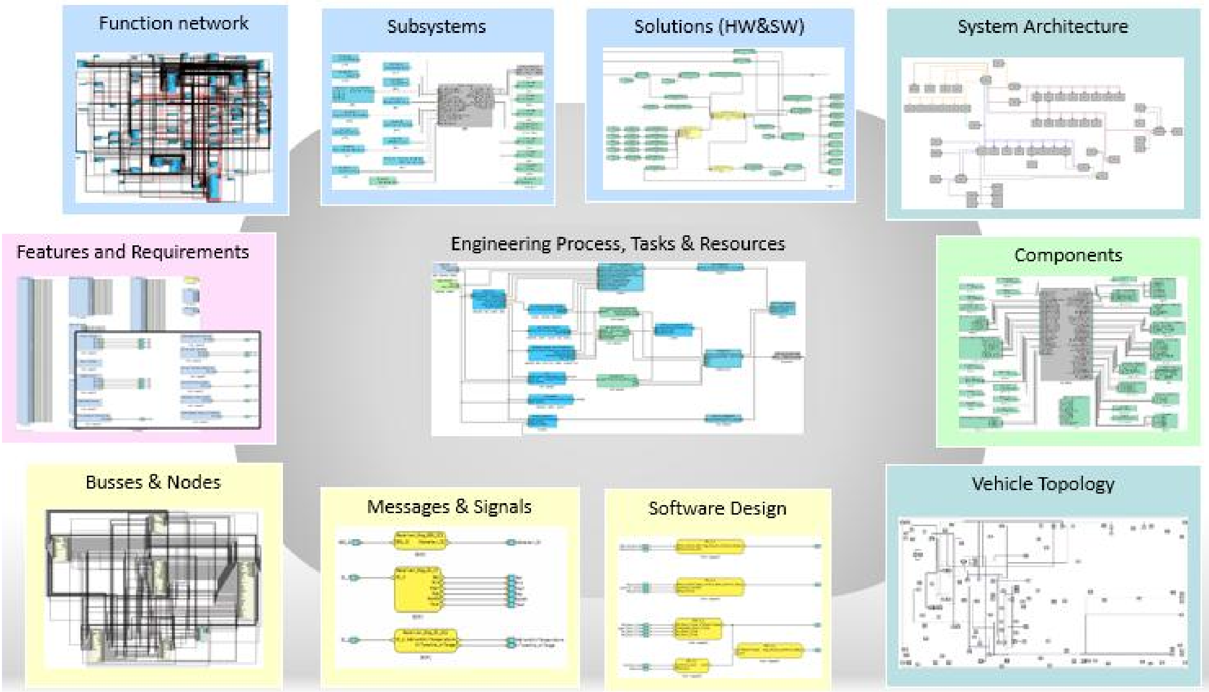

Figure 3: Examples for graphical views on the vehicle reference model

Graphical modelling of engineering objects meets broad acceptance in China. Chinese characters are graphics with a certain meaning. It's not unusual that one of the team members who influenced the modelling methodology a lot is a master of calligraphy. All of the Chinese engineers have been taught to express things in pictures from childhood on. Thus the graphical representation of technical information like features, requirements or constraints isn't strange to them, but the logical continuation of a centuries old proven culture. Chinese people naturally use smart phones, it wouldn't be unlikely that they raise the question why information cannot be depicted graphically, even though this would make life a lot easier.

Engineering Objects

Information is managed in form of graphical „Engineering Objects" (EO). This can be information describing something (e.g. non-functional requirements) as well as system elements like a software module, a relay, the analog input of an ECU or a CAN message.

EO's always own the same basic set of attributes (User Access Rights, Description, Document-Links,...) as well as additional attributes according to their domain and use. They can be extended with any number of dynamic attributes. EO's communicate with each other via information objects called "Terminals". Terminals can be input or output of information and form the "interface" of an EO.

Engineering Objects can be handled with all PDM/PLM-systems, managed by version control systems, complemented by simulation systems or software and dependency information. Since all information is treated the same, the effort for the integration of tools and data along the whole process and across domains is limited to the transformation of EO's.

Mission Level

The process uses three levels of information specification. The „Mission Level“ presents a product/system on the highest abstraction level. It is described as a network of „Compound Functions“.

On mission level systems and subsystems are specified in a functional way. Functions can be referenced to real components, but the user is not forced to do so. Each function (or system/subsystem) calculates data like part costs, engineering costs and MTBF automatically from the data of it's children.

Each function/subsystem uses information objects („Terminals“) to interchange static or dynamic data with other functions. Terminals exchange information via „Connections“. Connections can depict data flow as well as control flow. Thus the hierarchical structured „function network“ is created, which is successfully used in the automotive industry since many years now.

Since Compound Functions can represent any type of information, networks of requirements or hybrid networks can be created as well. Hybrid networks are models representing e.g.

- all the features, functions and requirements in the same reference model
- all the electrical /HW-parts and the software in the same model
- all the software, the communication and the topology of components in the same model

Compound Functions can be defined without the need to „type“ its interface in the beginning, using “ANY” as the default datatype of terminals. This enables the user to freely create functions and networks even easier as with the well known VISIO. The tooling supports the user with e.g. automatic propagation of terminals between functions and offers to move functions in the hierarchical tree with automatic generation of interfaces and connections across all levels of the hierarchy. Typing of terminals can be done at any time of the project. The consistency of the data is controlled by the engineering system.

Solution Level

A second abstraction level is used to build a model of the solution of a function in a more close relation to the real world like hardware and software (control system model) or human resources and tasks (organization model). Such a model shall represent the approach of the solution, comprehensible and complete for knowledge sharing, reuse and documentation. A solution provides all elements which are needed to implement a function without having to map them to real existing components.

On Mission Level any desired structures can be created. When creating a solution for a control system function there is a distinction between elements with some hardware-part (HW-Types) and elements which represent pure software code (SW-Types). Solutions like e.g. the heating of the rear window (see *Figure 4*) are created as a „process chain“ (also called “chain of effects”). A process chain uses three kinds of transformation:

- process to electrical (here: „Activate heating“ by pressing a push button) and vice versa
- analog to digital (electrical value into bits and bytes, e.g. analog input) and vice versa
- digital to digital (process digital values by software)

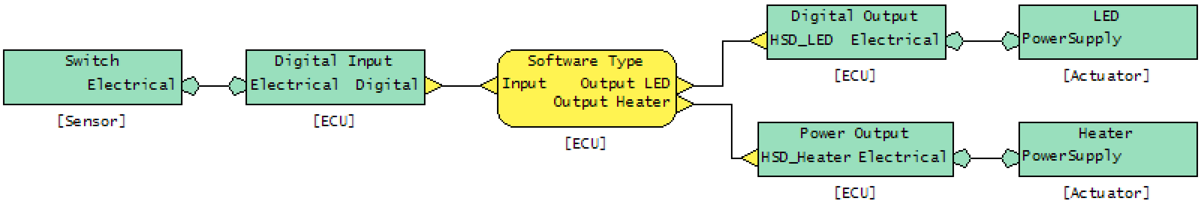

Figure 4: Virtual Solution Design-Model of rear window heater (transformations)

Model elements on Solution-Level are subject to the restriction of a clean type-instance handling. It's Engineering Objects are defined in a library first and then used („instantiated") in a model. The basic attributes of engineering objects are the same on both the Mission and the Solution level.

This philosophy enables PDM/PLM-systems to manage e.g. the whole CAN or LIN communication of a vehicle including busses, nodes, messages, signals and value tables for all variants and versions.

Implementation level

The implementation level presents the real components of a system. This includes the hardware components (e.g. ECUs, cables, fuses, relays, sensors, actuators, …), the implementation of SW-modules with their Simulink-model, UML-specification or C-code as well as the complete bus communication with busses, nodes, messages and signals.

The technical system architecture with ECUs and communication lines (CAN, LIN,…) is created on the implementation level. Model elements from both the mission and the solution level are mapped to real components. The need for real time communication is derived from the mapping, the engineering system automatically generates the signals in case two software modules exchanging real time information are mapped to different ECUs.

Domains of use and model coverage

During the development of the new vehicle platform the expert teams defined the data creation media, format and rules for each domain in parallel to the specification of the E/E-system. The 3E-team worked out the modelling methodology and developed the transformation tools, which generates the models from the data created by the domain expert teams.

The following table presents the reference model created so far with it's content in different domains and abstraction levels in detail.

Models	Mission level	Solution level	Implementation level	Libraries	Integration
Feature design	Marketing-features	Engineering features	Feature-description	Engineering-features	Excel
Subsystems	Subsystems, functions	Solution models, effects chain (HW&SW)	Components & communication, simulation	Subsystems, subsystems with functions	Simulink, RAPTOR, Excel
Functions	Functions	Solution models, effects chain (HW&SW)	Components & communication, simulation	Functions, functions with solution	Simulink, RAPTOR, Excel
Solutions	Function	Solution models, effects chain (HW&SW)	Components & communication, simulation	Solutions, Simulink/ RAPTOR blockset, dependency matrix	Simulink, RAPTOR, Excel
HW-types	-	Instance with additional attributes	Wiring & Connector/ Pin information	Electrical components, RAPTOR ECUs	Simulink, RAPTOR, Excel
SW-types	-	Instance with additional attributes	Simulink/RAPTOR SW blocks, C-Code, dependency matrix	Simulink/RAPTOR SW blocks, C-Code	Simulink, RAPTOR, Excel, Visual Studio
Electrics	function oriented, hierarchical reference model	Electrical components, wires, connectors, occurencies,...	ECUs, sensors, actuators, harness, cables, ...	Electrical elements (fuses, relays, sensors, actuators, ...)	EBcable, E3.series, Simulink, Excel
System Architecture	Vehicle reference model	Solution models	Components, bus systems, communication	reference architectures	Simulink, Vector toolchain,
Topology	-	-	Vehicle architecture reference model	reference architectures	EBcable, E3.series
Communication	Busses, nodes, gateways	Messages, signals	Datatypes, interaction layer, value tables	Messages, Signals, datatypes with value tables, bus protocols	Simulink, dbc (import & export), Vector-toolchain
Software design	SW architecture, tasks, functions	Software-design, MBSE, ECU-configuration	Simulink models, RAPTOR MBSE, Code generation	Simulink/RAPTOR SW blocks, C-Code	Simulink, RAPTOR, Visual Studio
Diagnosis (ODX)	ODX-functions	ODX-Requests & responses	ODX-datatypes and attributes	ODX-Requests & responses	ODX/PDX/Vector
ECU parameters	Vehicle variants	Vehicle features & options	hex-codes for production	Options	Excel, hex-code
Wiring & harness	Housing, cavities	Occurencies	Plug, wire, pin	KBL components	EBcable, E3.series

Figure 5: Vehicle reference model , domains, models and libraries

7. Tools

For such an ambitioned project a tool platform is needed which can handle a complete vehicle reference model with all the aspects of the E/E-system in full graphics without the need of simplification. The massive amount of data with thousands of graphical objects on one level, supported by autorouting, functional filtering, dependency analysis in both directions (fault effects analysis & failure back tracking) excludes tools which have been developed based on ECLIPSE[3].

There must be an open data schema based on the XML-Standard to be able to realize transformation of data and Engineering Task Automation. The authoring tool must be easy to learn, intuitive to use and available to everyone in the company. It must be able to communicate with the usual tools in the process chain (Simulation, analysis, software-design, requirements management, communication, wiring & harness,...) and dynamically adaptable to future needs. The engineering system shall be used at the OEM as well as on supplier side. Currently there is only on engineering system on the market which fulfils all these requirements. Therefore ESCAPE has been chosen for the implementation of the integrated, model based engineering environment at the CTCS. All the engineers can access the models, solutions and libraries thanks to a company's license.

[3] According to comment of Sky Matthews, former project leader ECLIPSE at IBM

8. Outlook

In China a lot of startups begin to develop a new generation of electrically powered vehicles. They get challenged by rising requirements on the E/E-system regarding reliability, safety, security and maintainability because of the connection to the internet and autonomous driving. The complexity grows despite the elimination of the traditional powertrain with all it's auxiliary units.

The E/E-Systems often are delivered by suppliers from Europe or the USA, but the knowledge about the solutions and the data is kept secret. This leads to a high level of dependence. A huge part of the added value flows outside the country.

The fully integrated, model based engineering presented in this paper collects the knowledge about the solutions and provides it to all participants of the process in an easy to understand and reusable form („Collect and share KNOWLEDGE“).

It empowers the user in it's literal sense of term to take control. The generic reference models available now reduce the time for the development of the E/E-system of a new car platform by half.

The next big step in the integration of the process is introduced in the development of a new EV in the USA. The software development is carried out with RAPTOR, delivering the model based software development environment, the production code generation and the diagnosis tools for remote access. The RAPTOR models are generated directly from the vehicle reference model. The software implementation thus gets part of the solution.

9. Conclusion

The age of huge, strictly hierarchical organizations in the engineering of vehicle control systems comes to an end.

The future belongs to small, specialized expert teams, powered by model based tools, solution libraries and engineering task automation. They are going to implement E/E-Systems in a friction of time and effort known today.

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