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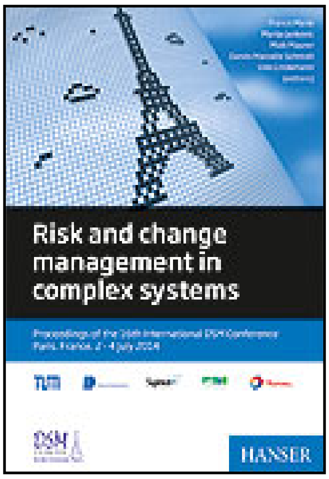

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Franck Marle, Marija Jankovic, Maik Maurer, Danilo Marcello Schmidt, Udo Lindemann

Risk and change management in complex systems

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Foreword

We are very pleased to welcome you to the 16th edition of the international DSM Conference.

The theme of this 2014 edition is "Risk and Change Management in Complex Systems". It is justified by the ever-growing complexity of our systems, involving the difficulty to anticipate potential indirect consequences of events, whether desired or not. Accordingly, this implies improvement of the methods and tools supporting the design and management of such systems.

Dependency and Structure Modeling (DSM) techniques focus on system elements and their interdependencies related to product, process and organization domains. They contribute to support mastering the amount of information required to better understand, model, and analyze, then make improved decisions to design and manage complex systems.

The International DSM Conference is the annual forum for practitioners, researchers and developers to exchange experiences, discuss new concepts and showcase results and tools. Hosted by Ecole Centrale Paris and organized in collaboration with Technische Universität München, the 16th edition of DSM Conference takes place in Chatenay-Malabry, France, during 2 to 4 July 2014.

Preceding this year's DSM Conference on July 2, will be a DSM Industry Special Interest Group (DSMiSIG) Industry Day workshop. Industry participants will contribute to the gathering of views and evidence of the risks in current product operations, from lack of advanced systems integration methods.

Regular attendees of the DSM Conference series will have noticed that a significant change has been introduced for this edition. The size of the paper is now 10 pages at most, without slides. This allocation expansion has allowed authors to put more details about their ideas, approaches and results. This was supported by the peer-reviews of at least two members of the Scientific Committee.

This volume contains 37 peer-reviewed papers, that describe the recent advances and emerging challenges in DSM research and applications. They advance the DSM concepts and practice in 7 areas:

1. DSM Methods and Complexity Management
2. System Architecture and Product Modularity
3. DSM in Decision-Making
4. Clustering and Optimization
5. Dependencies between tasks and processes
6. Process Management in Complex Projects
7. Managing Multiple Domains in Complex Projects

These Proceedings represent a broad overview of the state-of-the-art on the development and application of DSM. There are a significant number of papers with industry authors or co-authors, reflecting this balance and synergy between conceptual development and real-life industrial application, which are in the genes of the DSM Conference series.

The Organizing Committee

16TH INTERNATIONAL DEPENDENCY AND STRUCTURE MODELLING CONFERENCE, DSM 2014

PARIS, FRANCE, JULY 02 – 04, 2014

Applying DSM methodology to improve the scheduling of functional integration in the automotive industry

Thomas Gaertner[1], Sebastian Schneider[2], Christopher M. Schlick[2], Carsten Zibull[2], Cedric Heuer[2]

[1]BMW Group

[2]Institute of Industrial Engineering and Ergonomics, RWTH Aachen University

Abstract: Functional integration projects in the automotive industry are highly complex development projects, which are determined by multi-level dependencies, iterative processing, limited resources, last-minute changes, and a multi-project working environment. In order to avoid project delays and quality issues, this paper presents a novel generic project schedule for functional integration projects based on the Design Structure Matrix methodology. This is intended to improve the planning of project timelines and required resources and capacities, to ensure tighter synchronization between the project teams, to serve as a guide for prioritizing tasks in parallel projects, as well as to serve as a basis for anticipating changes to the project stages when development changes or delays need to be accommodated.

Keywords: Project planning, project scheduling, functional dependencies, functional integration

1 Introduction

The dynamic response of modern vehicles found in areas such as acceleration, load changing, and fuel consumption and emissions are determined and set by a large number of electronic controls. Within the premium automotive segment, customers expect vehicles to operate faultlessly and exhibit optimal response behavior in any driving scenario. To facilitate precise and accurate control at a granular level, the software functions are perfectly matched to the engine and the vehicle as a whole through the calibration of system parameters, including specific values, performance curves, engine maps and physical models (Mitterer, 2000). This process, which can be highly complex, is described as functional integration. The calibration process is one of the key elements to shape an OEM's brand profile (Weber, 2009), and it is thus one of the development tasks usually carried out in-house – even at a time when development is increasingly outsourced to suppliers. Due to the growing number of software programs being integrated into automobiles and also due to higher demands on the states of driving, today's premium vehicles typically require the setting of tens of thousands of calibration parameters, with many more yet to come. The functional integration of the power train makes it necessary to coordinate a number of very different disciplines such as driving response, fuel consumption and emissions, as well as the strategy for using the electric motor or combustion engine in the case of hybrid vehicle systems.

The functional integration for these different subjects cannot be implemented independent of one another, as the areas are highly interdependent. Frequently, the calibration is required to resolve not only single problems but also multiple, conflicting objectives. For example, most functions need to be calibrated over and over until the power train response perfectly matches the customer's dual expectation of minimum fuel consumption and emissions and maximum vehicle dynamics in any driving scenario. Consequently, every design engineer iteratively fine-tunes their calibration parameters right up until the project deadline. A delivery schedule for the functional integration process that resolves the conflicting objectives of multiple subjects still needs to be developed.

Functional integration, then, entails a number of highly complex projects. These are determined by the following factors:

- Multi-level dependencies, such as between engine, gearbox, hybrid components and the overall vehicle
- Calibration tasks spread across different organizational units
- Iterative processing
- Limited resources, e.g. test vehicles
- Possible delays caused by upstream development issues
- Last-minute changes and new requirements
- A multi-project working environment

The described complexity can cause problems in the development process, forcing OEMs to make costly investments in order to avoid project delays and quality issues.

The dramatic rise in software functions and calibration parameters experienced in recent years has so far been met by increasing staff numbers. Given the growing volume of variants and cross-functional requirements, however, an in-depth revision of functional integration working methods and working structures is needed.

For this purpose, a new project was launched to develop a generic project schedule for the functional integration in vehicle development projects. This is intended to address the following objectives: (1) In order to improve the planning of project timelines and required resources and capacities, a project-specific functional integration schedule based on an overall generic project schedule is to be established. (2) The project schedule is to ensure tighter synchronization between the organizational units (such as engine, gearbox, hybrid, overall vehicle). (3) The project schedule is to be compatible with subject-specific schedules and thereby ensures transparency and simplification. (4) The project schedule is to serve as a guide for prioritizing tasks in parallel projects. (5) Project maturity is to be measurable, thus facilitating early identification of deviations and on-time corrective and support measures. (6) Lastly, the schedule is to serve as a basis for anticipating changes to the project stages when development changes or delays need to be accommodated.

2 Structural and process scheduling

The established approach to generating a project schedule (Kerzner, 2009; Shtub et al., 2005) is to first divide the project into its constituent work packages using an object-, function-, timeline- or process-oriented breakdown structure. These work packages are defined both quantitatively and qualitatively, and refer to detailed tasks such as calibration activities and solution finding. The aim of this is to delineate the contents and intended results of the individual work packages. Furthermore, the tasks that must be completed, as well as the parties responsible for them, need to be clearly defined. On the level of the individual processes, detailed time scheduling needs to be prepared. Of particular importance is the identification and specification of interface points, i.e. the points where individual work packages are linked.

During the planning of the process schedule, the previously compiled and specified work packages are distributed across the project timeline. The project schedule provides a visual representation of the logical and chronological structure of the work packages across the project. The project schedule also specifies when the individual steps need to be completed in order for the ensuing steps to commence (Shtub et al., 2005). Critical points in time, such as the completion of sub-goals, are highlighted as milestones; these divide the project timeline into more manageable stages.

3 Applying DSM to the planning of functional integration

Due to the high level of structural complexity in the functional integration projects as well as the high level of dynamic complexity, there was little point in creating a project schedule and depicting the sequence of calibration activities without extending the above-described methodology. The high level of structural complexity in functional integration (Cardoso, 2006) is caused by the diversity of calibration tasks, the large number of dependencies and also the different types of dependencies, such as functional or organizational dependencies. The dynamic complexity of functional integration projects (Senge, 2006) is due to the dependencies in the calibration process not being static across the project timeline, for example, because of needing to accommodate other calibrated parameters or functional revisions; calibration activities may have local effects as well as effects on other calibration subjects, and dependencies may furthermore have unexpected outcomes. Where a large number of interdependencies are present, pre-defined supply chains are needed to manage these. Such supply chains need to specify which calibration characteristics need to be achieved when, by whom, at which maturity level, and who relies on each of the characteristics. When there is a common definition of the (interim) outcomes to be achieved at the interface points and their deadlines, synchronization of the project teams is much more structured than by just giving a definition of the activities. This can be illustrated by the following example: For the purposes of synchronizing functional integration, the statement that an engine calibration is being trialed for winter usage at a certain time is less relevant than the statement that the engine will be able to start reliably at -20° C at a certain time. Consequently, the generic project schedule is focused on milestones and synchronization points rather than activities. The description of the supply chains comprises the contents of the generic project schedule. It was put together as follows:

7. Compilation of a project breakdown structure
8. Identification of the dependencies between calibration subjects; documentation within a Design Structure Matrix (DSM)
9. Specification of dependencies in reference to the project timeline and calibration maturity using SIPOC diagrams

10. Identification of closely-linked work packages through DSM-based clustering
11. Process scheduling

3.1 Compilation of a project breakdown structure

Firstly, a top-down project breakdown structure was compiled for systematically ordering the functional integration process. The first level of this shows the object orientation of the calibration process, which is in reference to the 26 calibration subjects (such as the gearbox calibration); the second level shows its timeline orientation. For this, each calibration subject is subdivided into four generic stages with pre-defined maturity levels. This not only facilitates an easier overview but also provides a rudimentary tool for monitoring project progress. The functional integration thus consists of 104 work packages.

3.2 Identification of the dependencies between calibration subjects

Based on the 26 calibration subjects, a DSM was created that shows the main dependencies between the subjects. To identify the relevant dependencies, individual and group surveys of experts were conducted for each of the calibration subjects. The entries in the subject rows are based on the replies detailing the dependencies of each subject. The columns, on the other hand, state which other subjects are dependent on the row's subjects. The interviews with the experts showed that an calibration subject's dependency on other subjects is unlikely to cause issues. Conversely, the experts found it more difficult to identify other calibration subjects that are influenced by their own subject. The result was a DSM with a large number of dependencies and interdependencies (see Fig. 1). This demonstrates the high level of complexity in functional integration and indicates the necessity of more detailed project scheduling, as well as that the calibration subjects need to be worked on iteratively and concurrently. Filling in this DSM together with those responsible for the different calibration areas primarily served to encourage further thinking about the dependencies and interdependencies. This was a good door opener for detailing the work packages.

3.3 Specification of dependencies using SIPOC diagrams

To obtain a detailed description of the dependencies between the work packages, the experts of the calibration subjects in question were again surveyed to document which interim outputs need to be achieved by other subjects and which additional requirements need to be met by the specified deadlines in order for the project to be completed. In order for the project maturity to be measurable, the (interim) outputs also need to be quantifiable. This way, measuring the achieved outputs can provide feedback on the maturity of the work package. E.g.: Within one of the gearbox work packages, a specific preciseness of supplied engine torque is required at a specified time. This request may be included in all of the gearbox's work packages, but over the course of the project, it will become more detailed and stricter. Note, however, that a function – or the calibration itself – will only mature linearly during development if the same hardware and software is used. When a function is migrated to new hardware, it usually has a lower maturity level than with the old hardware; in this case, it first needs to be elevated to the existing maturity level via the calibration.

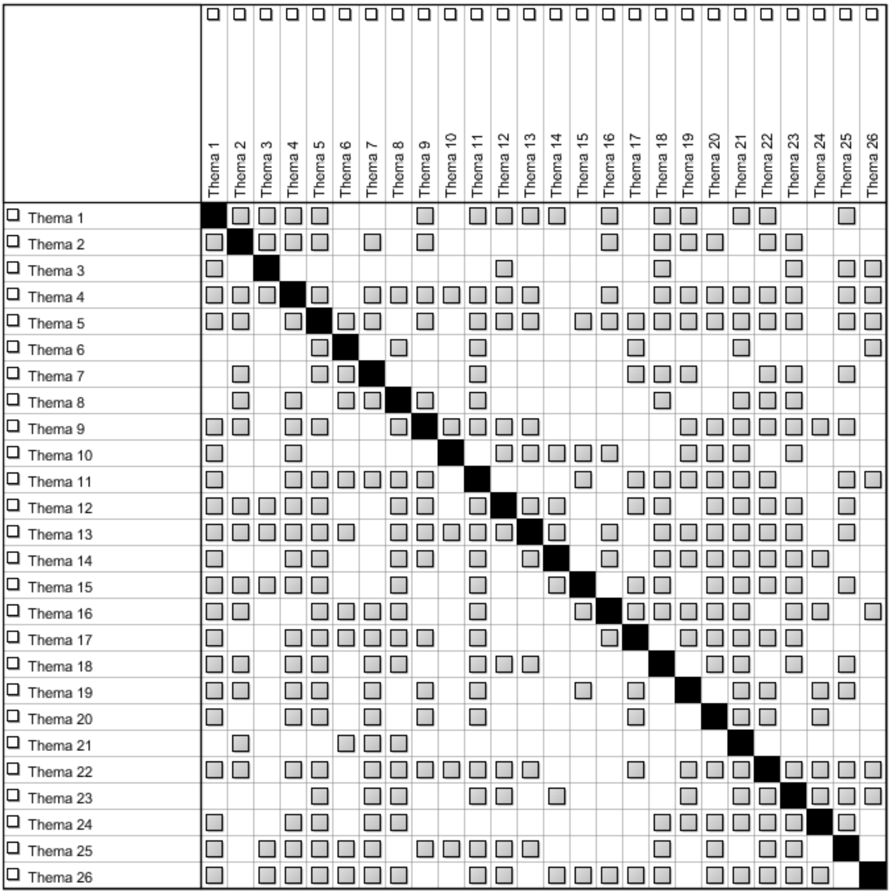

Figure 1. Dependencies between calibration subjects

For the potential delivery deadlines, points within the project timeline known to everyone working on the calibration process were selected. Also surveyed were the time spans needed for completing the individual work packages, the most important technical functions, the throughput times, and all the required personnel capacities and resources. For each work package, the data was documented using so-called SIPOC diagrams, which were expanded to include a chronological level. SIPOC diagrams are very useful process models for describing the process's supplier, input, process, output and customer elements (Pyzdek and Keller, 2009). For the methodology at hand, the outputs correspond to the inputs requested by another calibration subject (see Fig. 2).

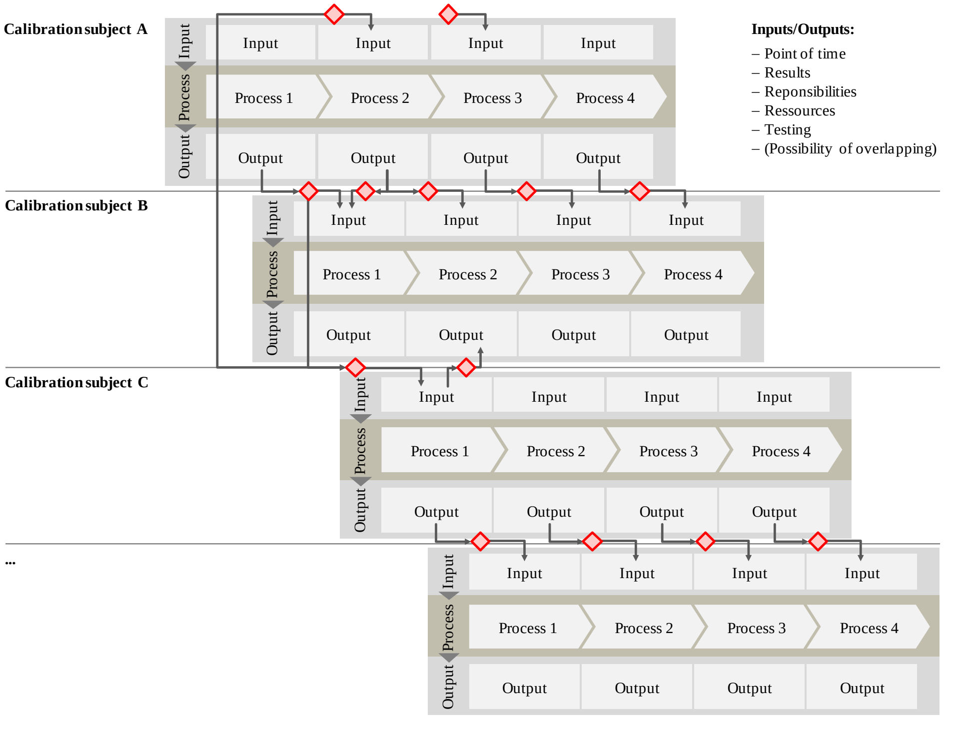

Figure 2. Linking of SIPOC diagrams

3.4 Identification of closely-linked work packages

In order to identify closely-linked project work packages, a clustering process based on the DSM was used (Steward, 1981; Yassine, 2010). The Cambridge Advanced Modeller was deployed as a tool for this (Wynn et al., 2010).

The dependencies between the work packages of the calibration subjects documented in the SIPOC diagrams were transferred into a hybrid DSM consisting of the 104 object and function-oriented work packages. Each input-output relationship between the calibration subjects represents a dependency in the DSM; this is in relation to the maturity stages. Entering the dependencies gathered in the interviews would also have been possible using the DSM. However, the SIPOC diagrams are much more intuitive and easier to use than the DSM. Also, working with SIPOC diagrams is always in relation to the relevant section of the DSM. This makes it easier to fill in the DSM when there are widely distributed dependencies. The hybrid DSM derived from the SIPOC diagrams is displayed in Fig. 3.

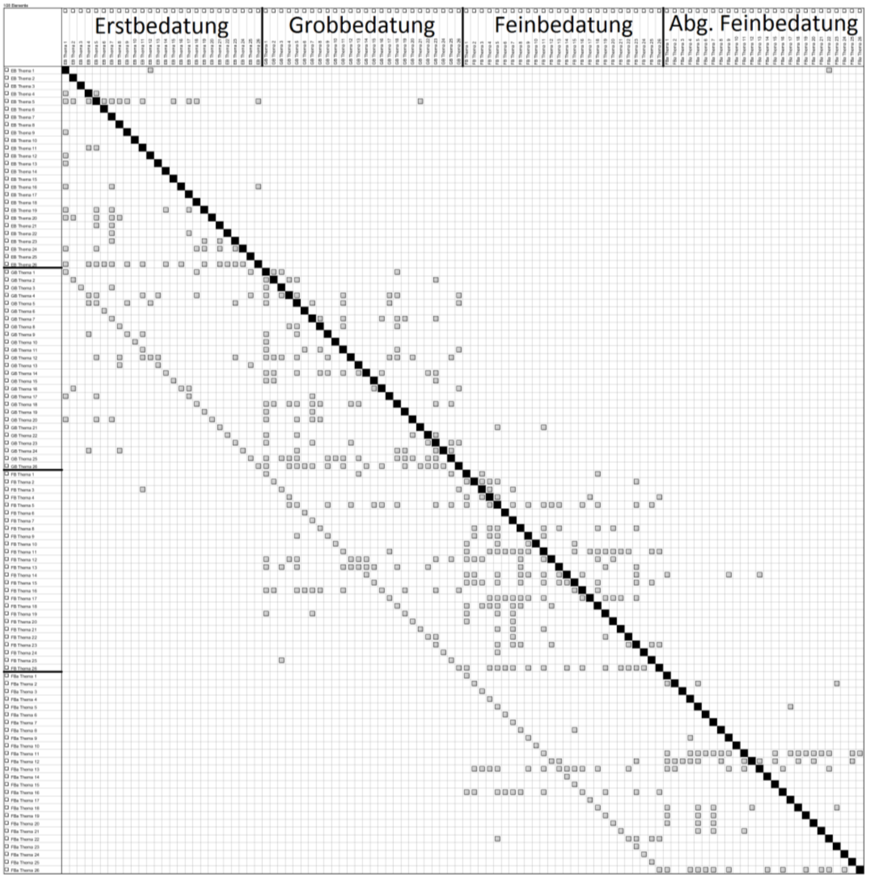

Figure 3. Hybrid DSM with dependencies between calibration subjects in relation to maturity stage 1-4

The hybrid DSM shows that most of the existing dependencies and interdependencies are located within the same stages of the timeline. Sequencing this hybrid DSM revealed that a purely forward-directed process cannot be achieved. To analyze the interdependencies between the calibration subjects within the individual maturity stages, the work packages of each maturity stage were manually compiled into clusters. Next, the clustering algorithm was again applied within each of the four clusters. The clustering result is shown in Fig. 4.

The correctness of some of the identified clusters can be confirmed already, as even nowadays project meetings are being held on these clusters to discuss the interdependent subjects. Comparing the clusters across the different maturity stages shows that there are both clusters containing dependencies that remain stable throughout the project, as well as clusters that differ distinctly from the clusters in the other project stages. To address this, the calibration teams should meet in the best possible constellation upon reaching each maturity stage, for example, to conduct joint trials.

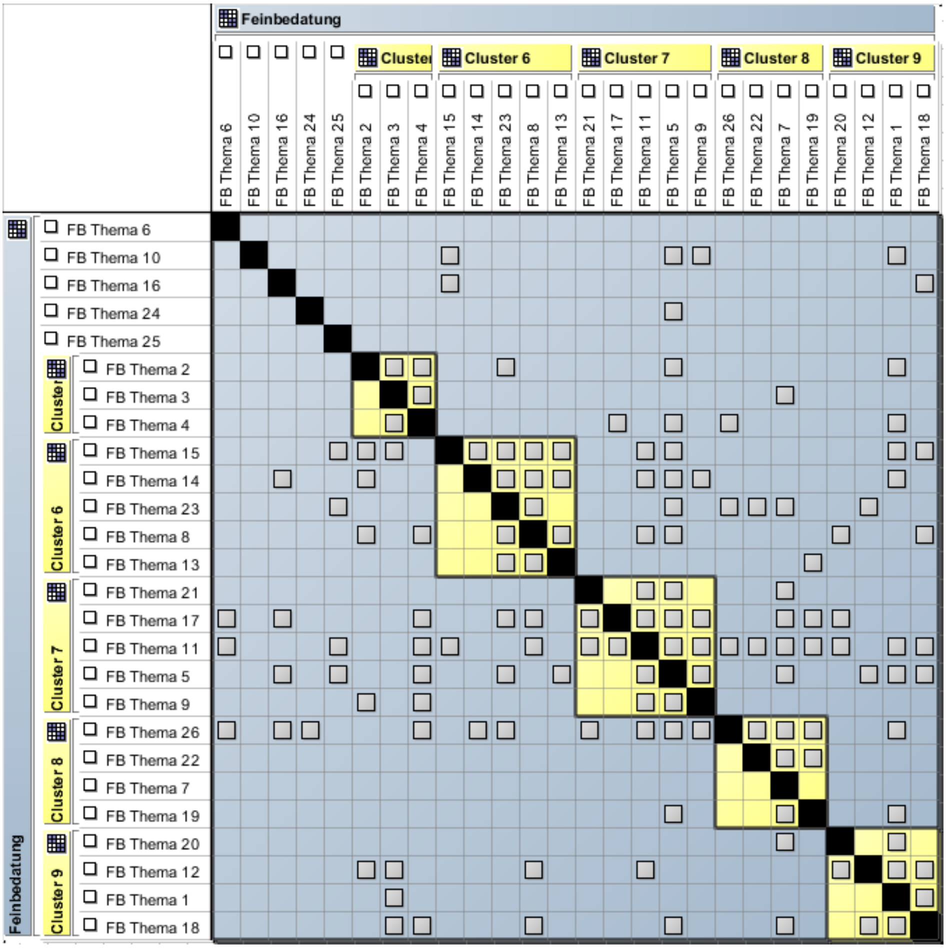

Figure 4. Clustered DSM for a maturity stage

3.5 Process scheduling

An overview of the function integration process was generated from the data of the SIPOC diagrams. This overview is known as the ‘generic calibration project schedule’; taking the shape of a Gantt diagram extended by links, it depicts all the main aspects of the calibration process. This includes not only the chronological dimension of the work packages’ maturity stages but also resources, trials, etc. A further level of granularity shows all the requested interim outputs as well as the dependencies between the calibration subjects. The design engineers are thus provided with a network of synchronization points that can be used as a starting point for the subject-specific schedules. These, in turn, describe how to achieve the required results in reference to the input data.

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