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CHALLENGES FOR CAX AND EDM IN AN INTERNATIONAL AUTOMOTIVE COMPANY

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Abstract

In design and manufacturing of passenger cars, changes in processes and tools pose new challenges for the management of engineering data. In this paper, the status quo, challenges, and developments are elaborated using the example of a globally operating automobile manufacturer. Special attention is given to the complexity and variance of the products, to paradigm shifts in design philosophies, to trends targeting the IT environment, and to user bias. Finally, conclusions are drawn for future CAx and EDM[1] concepts and strategies.

Keywords: complexity, assembly-oriented development, engineering data management

1 Introduction

In line with the demand for shorter times-to-market, automobile manufacturers are forced to cut lead-times to the quick while, at the same time, continually increasing the complexity of their products. This trend is driving new concepts and strategies for product and process development. And management of engineering data and the organization and control of information flows both play a pivotal role.

This paper sketches the current situation in the automotive industry, depicting the latest developments and trends and addressing the resulting challenges and burning issues to be tackled. Then concepts and strategies for appropriate data management concepts geared to support the development process with a sustainable IT concept are introduced and discussed.

2 The Status Quo

The product creation process in the automotive industry is complex. Not only is this true for the products themselves, i.e. the automobiles, which are continually growing in complexity to meet market demands: carmakers are also confronted with a need to integrate a soaring number of electrical, electronic, and software components in what used to be a chiefly mechanical system landscape. In addition, an explosion in the number of variants per model due to the trend toward mass customization, which strives to tailor-make stock cars to specification, continues to put pressure on the industry.

On the other hand, there are a multitude of organizational aspects which significantly impact product development. For example, experts from a variety of domains both within a wide

[1] This paper uses EDM as the collective term for engineering data management, product data management (PDM), and product lifecycle management (PLM).

range of intra-company departments and from external organizations are typically involved in the development of a single passenger car model. Thus the effective and efficient exchange of information between all these people and the systems involved in the overall process is paramount. And the requirements and needs of the individuals making up this complex need to be transparent in order to prevent a loss of information, duplicated tasks, and redundant data.

In state-of-the-art development, product and process activities are now geared to run largely in parallel, striving to reap the benefits seen in simultaneous or concurrent engineering. The call for minimized development times makes it imperative that tasks be structured efficiently and the workflow coordinated effectively. This therefore drives a continuing process of change which affects the process landscape. In addition, the endeavor to cost- and time-optimize the iteration loops occurring during product creation is pushing the general vogue toward front-loaded development, i.e. shifting of development steps to the early phases of the product development process.

A wide variety of computer-aided tools on the market promise to support individual stages in the process. Yet, taking advantage of these enabling tools has led to a drastic increase in the heterogeneity of IT systems in the automotive industry: the system landscape now often resembles a jumble of stepping stones leading through the development path (see Figure 1).

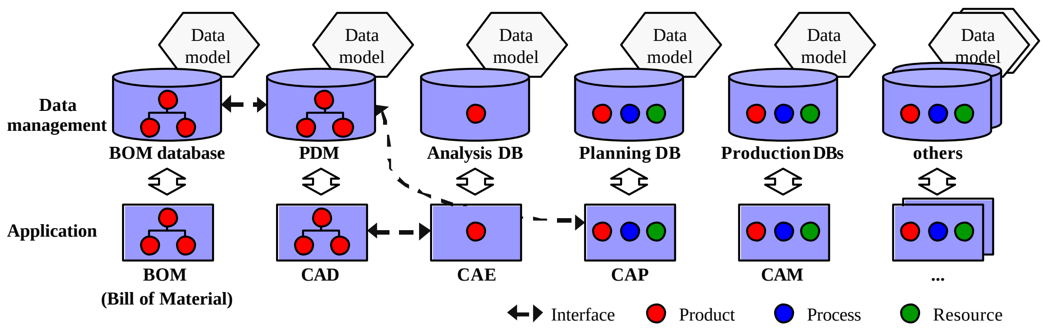

Figure 1. The Present: A Heterogeneous System Landscape.

While these systems attempt to provide optimum support in the areas they are tailor-made for, due to the high degree of specialization necessary they tend to form only partial solutions. In fact, many of these tools are proprietary in nature or, if bought off-the-shelf, have been customized to a large extent, thus generally necessitating a great deal of effort for maintenance and extension. What is more, data exchange between these islands is difficult if not sometimes impossible to achieve. The obvious remedy to this problem is a move to integrated solutions. And this demand has been answered by system houses who have reacted by extending their product portfolios through acquisitions of competing products or extensions of their own solutions.

In product development, deployment of digital tools has become wide-spread. Design systems support product styling and design and, with each new version launched, integrate more and more functionality. Where the introduction of 3-D CAD systems initially promoted part-oriented design, assembly-oriented approaches (and, with them, the management of the related information) now stand in the limelight. Today the 3-D model has taken over the function of a digital master, incorporating and integrating all product-relevant data.

In downstream process steps such as production planning, the use of digital tools is not as common. Yet in many modern enterprises there is a clear movement toward establishment of the digital factory for manufacturing of the digital product.

All of these trends have brought with them a considerable increase in the effort required for effective data management. Not only does this apply for the pure volume of data generated, this also holds true for the links and internal relationships between the various data types and the organized access to distributed data.

3 Challenges Due to Growing Product Complexity and Diversity

As the situation depicted above and the trends described illustrate, a number of challenges have arisen for the automotive industry as a result of the growing complexity of the products manufactured and the sheer diversity of the product portfolio.

This following section addresses the burning issues of electrical system, electronics, and software integration in the product and the rise in the number of model variants.

3.1 Integration of Mechanical, Electrical, Electronic, and Software Components

The integration of electrical, electronic, and software components in what was for almost a century a mechanical engineering-oriented discipline has posed diverse challenges for data management in automobile design. Now, new disciplines and organizational units work together and new kinds of information are generated, e.g. software programs whose management was previously unconceivable. As a result, functional interrelationships which by far overreach the purely mechanical connections have cropped up between these innovations and the conventional information generated. It is the task of data management systems not only to represent and administrate the data and their interrelationships but also to ensure trouble-free change management in spite of the different discipline-specific change cycles involved.

3.2 Variant Management

Some years ago, the carmakers' product portfolios were characterized by an evident trend toward consolidation. But now they have made an about-face, attempting to fill consumer demands over the full range of the spectrum from the lean-equipped economy car to the comes-with-all-extras premium model. Nowadays customers are encouraged to build-it-yourself, able to select from a wide range of extras and features. Depending on the manufacturer and model, just about anything goes and the number of possible variants has exploded. Figure 2 depicts the development at a major German carmaker. This customer-oriented build-it-to-spec mentality is coupled with the cost-minimizing notion of volume production to culminate in what is often spoken of as mass customization. However, apart from the above-described variants which primarily focus on modified extras, parts or styling for marketing reasons, there is a need to manage further kinds of variants. For example, development and production require representations of the placement options for standard parts often used in the product, of alternative concepts or even of different prototype or release versions. In addition, process variants such as those called for due to the different manufacturing processes in place at different production sites may boost complexity.

Currently, neither the methodology nor the systems used in management of engineering data relevant for representation of product variants in the automotive industry are uniform. A variety of methods are employed (numbering logics, coding, etc.) with, on the system side, bills of materials (BOM) and/or EDM systems supplementing the paper-based management of the variants.

As a rule, variants are not managed in CAD systems as the leading system vendors do not support this functionality. Many CAD-side concepts are mature when it comes to the representation of products with only few or no variants. Geometry models are saved in individual files with no variants considered; combining these files by means of other systems enables the design of variants. Thus, if complex products are to be represented, the CAD systems employed need to mesh well with the EDM systems utilized.

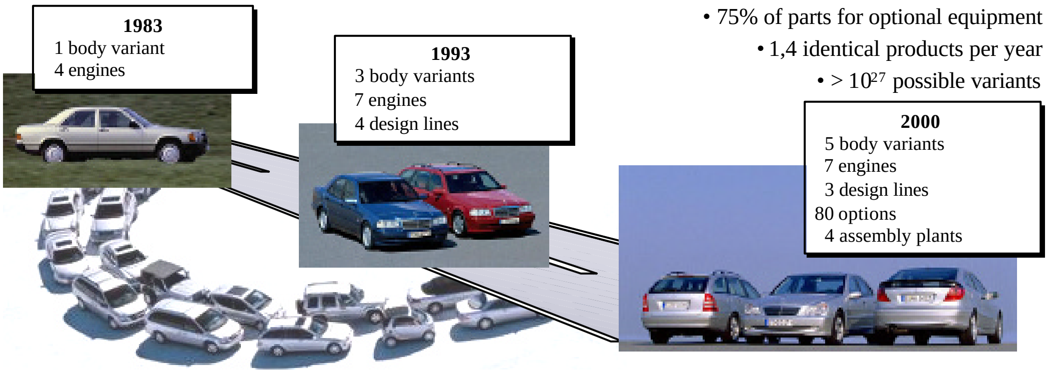

Figure 2. The Wide Product Portfolio Necessary for Today's Carmaker.

4 Challenges Due to a Paradigm Shift in Development

Further challenges have resulted from the shift in development philosophies: buzzwords such as assembly-oriented development, front-loaded development, and the digital product master have replaced previous paradigms.

4.1 Assembly-oriented Development

An era ago at the time when design was based solely on technical drawings or later with the use of 2-D CAD technology, design was traditionally top-down, i.e. the initial draft was created at the drawing board on the product level. This drawing contained both underlying part geometries and the information needed for assembly. Detailed design was done at later stages in development, with drawings of the individual parts derived from the holistic product view.

With the introduction of 3-D CAD systems this world turned topsy-turvy and a bottom-up philosophy was embraced. Thus, the more-or-less detailed modeling of individual parts became the first step, with assemblies then created on the basis of the information derived. In fact the original draft on the product level had to be made outside the 3-D system and frequently existed only in the minds of the design engineers. The severest impacts occurring due to this paradigm shift tend to show up in a changeover from 2-D to 3-D design.

In the meantime, however, the importance of design concepts on the one hand and of assembly-related information such as constraints, kinematics, links or tolerances, on the other, has been recognized, resulting in the development of suitable top-down methodologies for 3-D design. An excellent example for this is skeleton modeling [1]. While CAD system vendors have largely adjusted to the trend toward assembly-oriented design, management of the data generated has remained problematical. Chiefly part-oriented in nature, EDM systems find it difficult to handle the complex and oftentimes non-transparent relations between the individual parts of an assembly.

Moreover, release processes do not sufficiently reflect the shift: organizational workflows have frequently not made a commensurate shift from part-oriented to assembly-oriented processes, partly because of a lack of systems supporting them.

Figure 3 depicts the development of design philosophies and technologies.

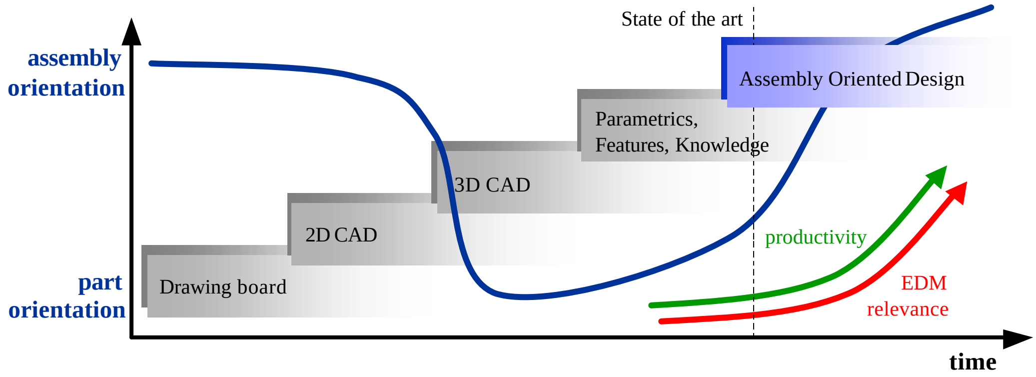

Figure 3. Paradigm Shifts in Design Philosophy.

4.2 Front-Loaded Development

It is well known that the greatest proportion of product costs is determined by decisions made in very early phases of development and that the later subsequent changes are made, the more expensive they become. Consequently a trend toward so-called front-loaded development has arisen: as many of the related planning activities as possible are packed, i.e. loaded, into the early development phases. The objective is to reduce the number of later changes needed and to minimize time-consuming iteration loops, thus accelerating the overall product development process [2]. To be able to make the right decisions at the right time necessitates new, powerful tools which would enable the reliable estimation of the consequences and effects of planning and design decisions on product characteristics at earliest design stages. Moving design activities forward to early phases has broken up the classical sequence of operations as used to be typical for development. Also, the pressure put on manufacturers by the market to develop quality products within increasingly shorter time frames has reinforced this trend toward sequenceless development.

Front-loaded development and sequenceless development not only set new requirements for the tools supporting the product development process, they also require engineers to acquire a new slant on the related process flows. The purely organizational approaches currently embraced, which typically target cooperation between the various departments through the establishment of interdisciplinary function groups, frequently no longer meet certain demands. Information on the current status of development work has to be made directly available to all those involved independent of any approvals or releases. Knowledge that design engineers have stored in their own systems, in particular, has to be made available for use to downstream engineers.

Yet front-loaded development in no way means that the designer alone is responsible for considering all of the relevant aspects at the beginning of product development. Rather it calls for collaborative working between the specialists from design, production, sales, after-sales, and waste disposal and recycling from the first idea on.

4.3 Digital Product Master

As already mentioned, a further aspect to be considered is the notion of the digital master, which moves design further away from the drawing board and conventional release processes. The underlying concept is to integrate all of the relevant information in the 3-D model, thus largely eliminating the need for derivative drawings and/or other documents generated within the design process in parallel.

Due to the wealth of part and assembly data required in downstream processes this is a complex task, especially taking both the quantity and the quality of the data generated into account. Yet it is not only the product modeling methods that need to be adjusted, the processes along the design chain will have to accommodate special aspects: e.g., releases and signatures need to be effected in the model and saved while the mandatory periods for archival of documentation will pose a particular challenge for today's short-lived system environment.

5 Challenges Due to a Dynamic IT Environment

Due to the trends cited in Chapter 4, an impact on the IT environment is unavoidable. Apart from this necessary tool integration into existing structures, the consolidation of software vendors and the need to promote integration of supplier data and processes into the corporate IT infrastructure are driving new requirements.

5.1 Integration of New Tools in Legacy Infrastructures

In many industries the IT system landscape has run wild. And in the automotive industry in particular, this has become progressively problematical due to corporate growth and globalization strategies. Over the years, the number of IT systems deployed in the product creation process has soared; the systems have been subjected to a process of continual optimization; they have been extended and customized to the requirements of the individual applications. Yet, owing to the absence of a uniform product, process, and resource description language, the potential inherent in each and every one of these tools is not even near being fully exploited. As Figure 1 depicts, suitable interfaces are missing or are able only to transport a small proportion of the overall information from one system to the next. Thus, data from upstream processes need to be interpreted and often manually re-input, which is not only inefficient but also facilitates the creation of redundant data relevant for the same product. The farther-reaching consequence is that changes made to a product result in numerous updates to data in the various data islands. The imperative changeover to holistic digital support, which is intended to alleviate this, demands innovative concepts. And it will surely be a key task in the near IT future to develop, validate, and firmly establish such concepts.

A uniform data and process model will have to be set up to enable direct reuse of the data once generated and avoid interruptions in the media flow. A common data repository is the prerequisite for direct communication and access to the current status of development at any time and from any system in the process. For only a common data repository will accelerate development and boost quality.

5.2 Consolidation of Software Vendors

A further impact follows from the changing landscape of the system suppliers: mergers, strategic alliances, and acquisitions have led to the market dominance of the few large system houses which have swallowed up the others. Thus, lately, many EDM functions have been integrated into CAD systems – a clear reaction to the customer's desire for continuous solutions utilizing a common database. In fact, the large CAD systems seem to have been extended to all-encompassing engineering tools able to cover all the bases: no longer geared purely to generate geometries, they now cover simulation and analysis activities and even tackle data management for all the relevant areas. So what about the highly specialized system from the small, niche vendor that is needed? Or the proprietary software developed in-house for a special application? Where is their place in this all-in-one architecture? Experience has shown that there are two basic shortcomings: in addition to a shortage of open interfaces and universal data exchange formats, applications purchased by the vendors for strategic objectives, i.e. to meet customer demands, frequently incur significant integration problems.

5.3 Collaborative Working and Data Exchange with Suppliers

Nowadays, the engineering departments involved in product development no longer need to be located at the same site. Also, more and more parts are being developed in close collaborations with suppliers and service providers. This has resulted in communication issues to be considered on the system side. Supplier integration or change management – to cite only a few of the buzzwords – have placed a heavy burden on the information flow. To ensure that changes made during the progress of development work are passed on to all those concerned, it is no longer sufficient simply to save the data in a sensible structure in a central repository. There is more involved: both access to the data and update information need to find their way to the relevant parties, both inside and outside the concern.

Mastering the growing effort required to coordinate development calls for standardized processes and data. Thus, collaborative working inside and outside an organization and across sites is contingent on the agreement of common structures. And this puts pressure on suppliers to meet the stringent requirements of the manufacturer regarding procedures and processes as well as data structures and formats. And this complexity is a challenge to be met by those suppliers who, due to their cooperations with several large carmakers, are therefore forced to take over and work efficiently with the variety of comprehensive data models deployed.

6 Overcoming User Bias

New systems and processes necessitate that the engineers concerned develop new ways of thinking and working. Yet, people are fond of habits and are seldom willing to embrace change. The trends and concepts sketched in this paper, however, irrevocably lead to change, provoking shifts in tasks and responsibilities for those involved in the design and planning processes both inside and outside the organization. Despite the overall value added for the enterprise, the effort in the individual departments increases, sometimes considerably when, for example, activities from what were previously downstream areas are relocated into early development phases. Individual workers or even entire sections may not be up to handling the effects of this boost in complexity.

However, the expense of effort required and the benefits yielded due to the changes described frequently have quite a different impact on the various areas and phases of the development process. An analysis of the benefits expected for both the overall process and the single areas may be essential. Some changes following from a new development may be so far reaching that extensive restructuring of whole organizations and established structures is needed to implement them.

A useful tool in overcoming user bias and promoting user acceptance is work psychology. Work psychology techniques can smooth the way for change processes. People have to understand the need for a change to be able to greet it; the areas concerned need to be integrated in the change process as early as possible and be given a say in working out the concepts and strategies aimed at facilitating the change [3].

7 Concepts and Strategies

The aspects discussed above pose great challenges for the EDM strategy of the future. And a number of different concepts for how best to meet these challenges are conceivable. In any event, with a view on the process at hand, no matter which concept or system is in the end selected, the definition of tasks, interfaces, and hierarchies together with their boundaries is accorded top priority.

A key issue if product development times are to be cut to the bone is the storage and reuse of explicit product knowledge in downstream processes. All process-relevant information and knowledge has to be kept up-to-date and consistent and made available in the same form to all those involved in the process any time and any place; see Figure 4.

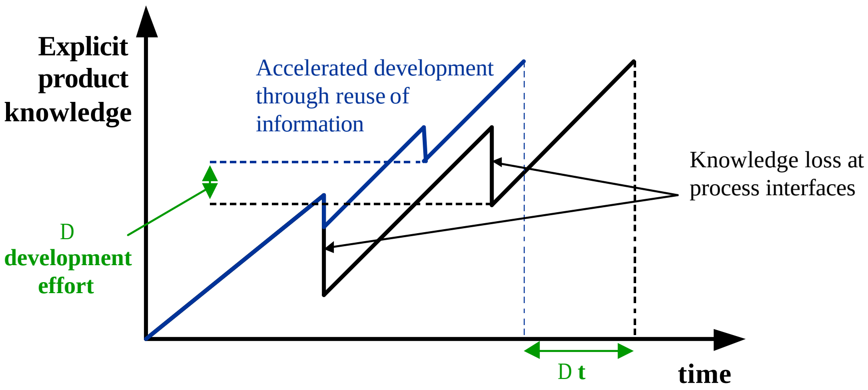

Figure 4. Accelerated Development Through Reuse of Information.

Many automobile manufacturers have made it a point to clearly separate the tasks making up the individual systems (this applies, in particular, for CAD/CAE/CAP and EDM). The product structure is managed in EDM and/or BOM systems whereas part-based geometries are generated in CAD systems and, if necessary, positioned and allocated to a specific structure. CAE (computer-aided engineering) and CAP (computer-aided planning) methods are often loosely linked to these structures. As a result, the EDM or BOM systems take on the role as master of the structure with the CAD system master of the geometry but assuming the slave role in the sense of the structure.

It is questionable whether this environment is able to effectively meet the challenges portrayed in the previous sections. In fact, the design philosophies discussed would appear to indicate the growing importance of CAD: it seems the system most likely able to take on the structure-related tasks arising from the introduction of new system solutions. The pivotal issue of variant management, which has so recently driven developments in the automotive industry, is certain to play a decisive role in how development activities are divided up between the various systems. In line with this, suitable systems are to be selected and extended to meet the carmakers' needs. And, in principle, any one of a multitude of more or less integrated or distributed approaches would be viable. A further aspect to consider is whether to purchase standard system solutions from vendors or develop customized concepts in-house. Yet independent of the concept selected - whether centralized or distributed in nature, it must be founded on the creation of a comprehensive data model capable of managing product, process, and resource data in order to avoid or at least control redundancy [4].

Large system suppliers such as EDS, PTC, and Dassault Systèmes now offer all-in-one systems slated to manage the entire engineering process chain and including CAD/CAE/CAP and EDM, in particular. Figure 5 illustrates the underlying concept. Hand in hand with the high level of integration achieved, however, goes a high level of dependency on the system vendor and its concepts – not to mention the usual difficulties in integrating third-party systems.

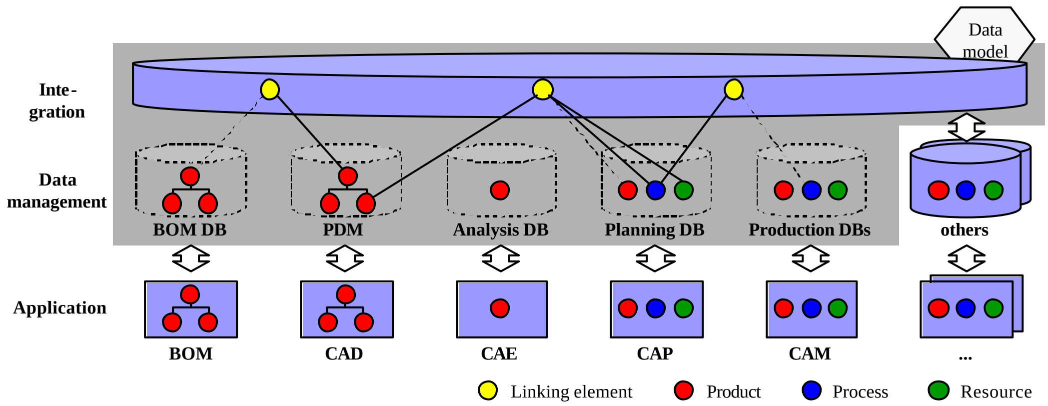

Figure 5. "All-in-One" Data Maintenance.

At the other end of the scale lies the notion of a suite of distributed systems (each customized for a particular area and optimized to best handle the specific tasks) linked together by a central system that defines the structures and determines how data is exchanged; see Figure 6. The umbrella system could be selected from the range of standard solutions on the market or be developed as a proprietary system able to control and manage both all the relevant information and any CAx tools deployed. Currently the trend is, in fact, toward evaluation of such a federated system, and investigations target the problems that might occur in integrating it into the development environment [5,6,7]. Such an environment could then support each process step as a system island with a suitable best-of-class IT solution. This approach places the focus primarily on enhancing the interfaces between these islands and a standard or proprietary master system and promoting the information flow. While this is expected to incur more effort within the organization, particularly if the central system is developed as a proprietary solution, the expected return would seem well worth it: freedom – freedom in the sense of independence from any supplier, the freedom to create and implement own process concepts, and the freedom to support each process step with a best-fit solution.

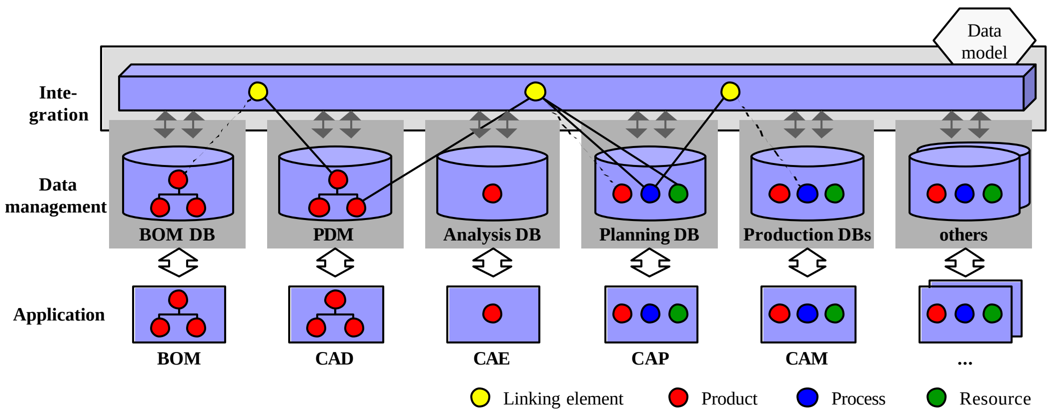

Figure 6. Distributed System Concept.

Between these extremes lies a wealth of other solutions, with either standard or proprietary system components. With respect to engineering data, the system boundaries from CAD to EDM seem to be melting away: design-related parts of EDM systems are being migrated to

CAD systems and EDM functionalities are frequently split up and shifted to design- or enterprise-oriented systems. These two core elements may form the hub for further systems, ensuring a productive information flow.

8 Summary and Conclusions

This paper provided an in-depth, inside look at current issues in product development of an international car manufacturing company, elaborating the requirements regarding the deployment of CAx and EDM systems which have arisen due to general trends in development and production. Any EDM strategy to be embraced will need to face the challenges posed. Future work will have to focus on the evaluation and validation of the approaches targeting this particular process environment in order to best support the development process with a sustainable IT concept.

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