SIMULATION PROCESS, DATA AND RESOURCES MANAGEMENT (SPDRM)

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ABSTRACT – Within an environment of a continuous intensification of product development, with fewer to zero prototypes, industry requires intensive, cost efficient and short CAE cycles with high confidence to their results, at earlier product development stages. Information that is needed downstream throughout the CAE projects is too often unavailable, untraceable, outdated or captive to error-prone manual methods. CAE's value is constrained by bottlenecks at data mining and dissemination. At the same time, CAE suffers from the lack of knowledge capturing and information reusability as the intellectual property that is gained by the collective experience of best-practices is lost.

Solution to the above is being sought on both individual CAE user and enterprise levels; a solution to efficiently handle existing resources (human, software and hardware) to co-ordinate and drive CAE operations and allow CAE managers, simulation engineers and operators to have a clear vision on what has to be done, how it has to be done, who, when and where should do it and of course over which data; a solution that captures CAE intelligence and is functionally capable of meeting the specific needs of all users; a solution that scales from a single user or workgroup to the entire enterprise and brings the concepts of contemporary engineering intelligence into the CAE simulation community in a simple and direct manner, suitable to today's work conditions.

This work serves as an introduction to the SPDRM solution developed by BETA CAE Systems S.A. for the needs of the contemporary automotive industry.

TECHNICAL PAPER

1. THE EFFECT OF INTENSIFIED PRODUCT DEVELOPMENT OVER CAE PROCESSES

In recent years the industry has been pushing for accelerated product development, better quality and of course reduced cost. Especially in the highly competitive automotive arena, the intensification of vehicle product development and the pursuit of innovative technology have changed the way we view CAE. Large OEMs are gradually elevating the importance of Simulation, place more confidence in it and hope to enter the "zero-prototype" era soon [1].

There is an inherent association between the focal points of vehicle product development and respective CAE processes, and it grows stronger as CAE moves further upfront in the development process [2]. On one side there is demand for more vehicle models, with more variations and options, satisfying tighter regulations and prepared at shorter time-to-market intervals. Mirrored to CAE on the other side, these translate to an increased number of simulations in shorter cycle times, with higher result reliability and at reduced simulation cost. In this context the growing complexity of simulation and analyses for new products brings CAE engineers in front of a new challenge: to improve CAE productivity and make CAE fast, flexible and efficient in order to identify deficiencies in time and suggest possible ways of improvement.

Any attempt to highlight the intrinsic difficulties imposed on modern CAE is likely to be incomplete. Aspects like the lack of highly skilled and experienced engineers, the amount of disciplines performing simulation, the growth of outsourcing and the need for global and

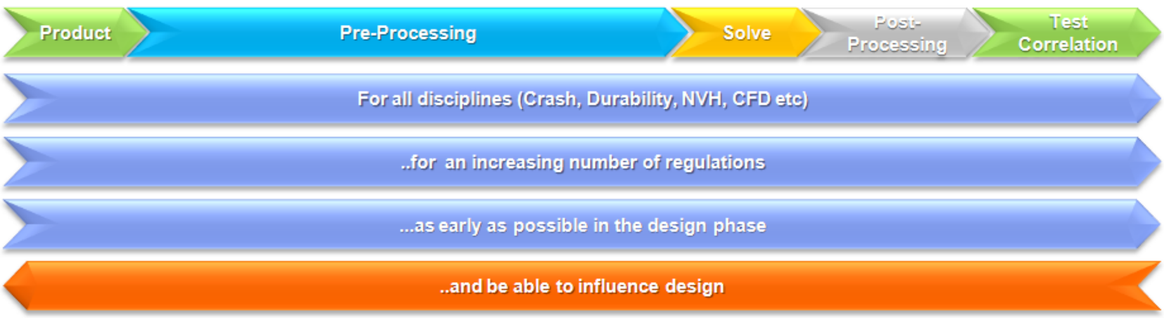

Figure 1 – Overview of CAE cycle

intercultural communication among engineers are just some representative examples that simulation managers and software houses need to take into account in order to adapt to the enterprise decision of speeding up product development. However, it finally comes down to simulation engineers and analysts to identify, capture and maintain the best practices of existing processes and proceed to significant improvements by using innovative breakthrough technologies [3]. In this context, modern automotive industry requires high-end tools to assist analysts in the build-up of an automated, robust and repeatable process workflow that will capture the proven practices and techniques used in a wide range of disciplines.

2. THE NEED FOR CAE WORKFLOW MANAGEMENT

To facilitate our argument for the need of managing the CAE workflow, let us focus on a typical CAE cycle followed within an automotive industry (figure 1). The cycle begins by reading the vehicle product structure from the enterprise PDM system, moves on to discipline model build-up for pre processing and solution and ends with the post-processing of results and their correlation to respective data from the physical test. This cycle has to repeat itself for all disciplines and for an increasing number of standardized or OEM-specific regulations. Moreover, in order to be able to communicate suggested product changes back to CAD, it has to be conducted swiftly and as early as possible in the design phase.

The previous presentation of the CAE cycle is very abstract and hides its complexity. Reality is different:

- CAE cycle is a process that involves a huge amount of diverse data, hence it requires a lot of data transfer which in turn reduces traceability
- it is spread over a number of departments with the risk of losing man hours due to lack of parallelization of actions
- it involves a large number of people with varying experience, making it difficult to maintain a high level of quality within processes
- it is hard to identify bottle-necks and dependencies, thereby reducing the chance of automation and repeatability
- it involves a variety of software and hardware resources, making it stiff to accept new breakthrough technology
- it involves actions within the enterprise and/or from external suppliers, and this involves the risk of leakage of enterprise knowledge

To the above, non-exhaustive list of aspects of CAE cycle that need management, we should add two more critical components: the delegation problem of who is doing what, where, when and how (with which data, which tools etc), along with the request for continuous progress monitoring.

Evidently we would need a high-end tool as a solution to the CAE workflow management. A tool that would serve as a wider, enterprise solution, to address simulation technology, methods, data and processes and manage the intellectual property associated with these. In the following paragraphs we will try to highlight the key-characteristics that are integral to this solution.

3. A SOLUTION FOR THE MANAGEMENT OF SIMULATION PROCESS, DATA AND RESOURCES

3.1. A process intensive approach

Towards shaping-up a CAE management solution, the very first thing we should do is free ourselves from the misconception that managing the CAE cycle is really about managing just the related CAE data. It is true that data are important and should be managed, but data are there whether we route them between actions or not; what we miss to make the data meaningful is to place them within the context of a process.

CAE cycle is by definition a process (a collaborative one actually) and covers a much wider field than just data. Thus, the management solution we seek has to be wider as well. It has to be an enterprise solution that is mainly process intensive, a solution which integrates the available resources needed to carry out this process and, finally, utilize the required data at each step of the process (figure 2).

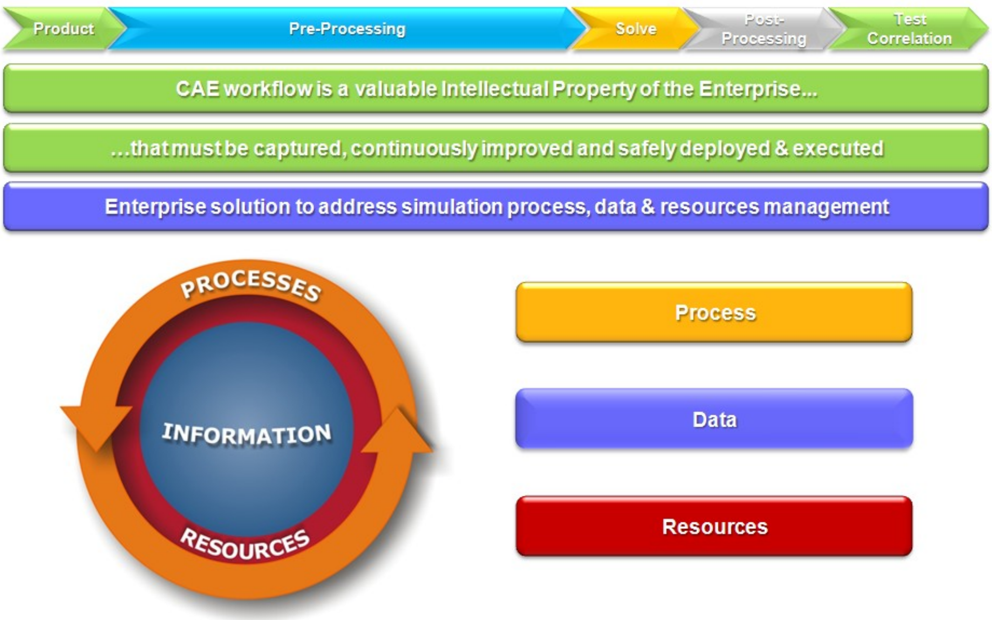

Figure 2 – A process driven approach to the management of CAE cycle

3.2. Weaknesses of available solutions

A number of commercially available packages today promise to address the CAE management problem. Unfortunately they either fall into the trap of managing just the CAE data, or lack the association between CAE process actions and available resources. Tools of the former category are often referred to as Simulation Data Management tools (SDM) and are by definition data-centric, aiming at routing data through different actions. They offer no means to delegate actions to resources and usually rely on other, external, software in order to provide a notion of guidance to user actions. Such tools are inherently non-collaborative.

Tools of the latter category can view the CAE cycle as a process in itself. They are known as Simulation Process and Data Management (SPDM) tools but still offer no resource management, maybe with the exception of communicating with the enterprise queuing system for problem solving. The major drawback of such tools is that they are built on non-efficient architectures, having a central server to manage the complete CAE process and related data. This involves the risk of poor performance as requests and transfer increase in number. To compensate, expensive specialized hardware and software is required to improve response, thereby increasing the cost of installation, configuration and maintenance.

3.3. Integrated process, data and resources management

Having discussed the approach that should be taken to manage the CAE cycle and learning from the drawbacks of existing tools, we are now in a position to outline the key characteristics of the Simulation Process, Data and Resources Management (SPDRM) solution introduced by BETA CAE Systems S.A.:

- it is process intensive and offers integrated control over data, resources and respective process actions
- it requires minimum IT effort to install, configure and maintain; it is adaptable to the existing organizational structure of the enterprise, so as to reflect the current structure of departments, workgroups, users and their respective privileges
- it is simple and intuitive to use
- it is scalable (from the enterprise level down to a department or a single individual) and promotes de-centralization throughout the enterprise or across its suppliers
- it is data and discipline agnostic, with no limitation to data-types and formats (so it can be used with any existing software tools that have been proven efficient within the current workflow); it is open to communicate with other software through standard or custom protocols
- it is a solution that promotes collaboration and adds consistency to all related CAE processes, but still remains flexible to adapt to new breakthrough technologies
- it solves the delegation problem by providing the right data to the right resource (human, software, department or supplier) for use with the right application within the right process at the right time

The aspects of scalability, de-centralization and job delegation of our SPDRM solution are discussed in more detail in the following paragraphs.

4. A NOTE ON SCALABILITY

The most comprehensive example on the scalability of SPDRM is depicted in figure 3, where a complete enterprise process is build-up in a sequential fashion:

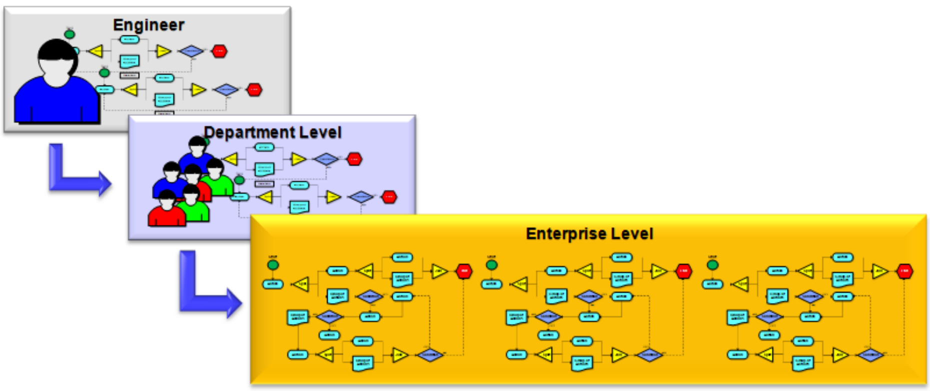

Figure 3 – Scalability in CAE workflow build-up

Every engineer has a specific work to do, using his preferred software tools and data formats. Using an SPDRM tool, the engineer can describe this daily work as his own sub-process that utilizes specific data from specific sources and has himself and other tools as resources to carry it out. Then, he can subsequently publish his own sub-process for integration into a higher level workgroup or departmental process. In this way the departmental work becomes an actual team work and little (or none) IT resources are required in order to reach at this stage, except maybe for a local installation of SPDRM that the engineer will use.

In a similar fashion, workgroup or departmental processes can be integrated into the higher level of a larger, enterprise process. Thus the complete workflow is built in a stepwise fashion from the lower towards the higher level, consisting of smaller sub-processes, each built by experts and thus capturing the engineering knowledge and expertise in every particular field. This simple concept can be applied even to the most complicated processes, eliminating the need for an individual guru that has knowledge of every single aspect of the complete workflow.

5. DE-CENTRALIZATION

An integrated process, data and resources management solution should be built on the concept of satellites. As we just saw, the complete CAE process consists of smaller, departmental sub-processes that in turn are further sub-divided into the processes of workgroups or individuals working inside each department. De-centralization is achieved by having all departmental and/or individual sub-processes carried out by local satellite servers.

Thus, whatever goes on behind a satellite is invisible to the central server and communication between them takes place only when the satellites are ready to contribute to the higher level enterprise process. As a result, all satellites plus the central enterprise server remain at a relatively low load (since each manages a part of the complete process), they are able to respond swiftly and the total traffic is minimal.

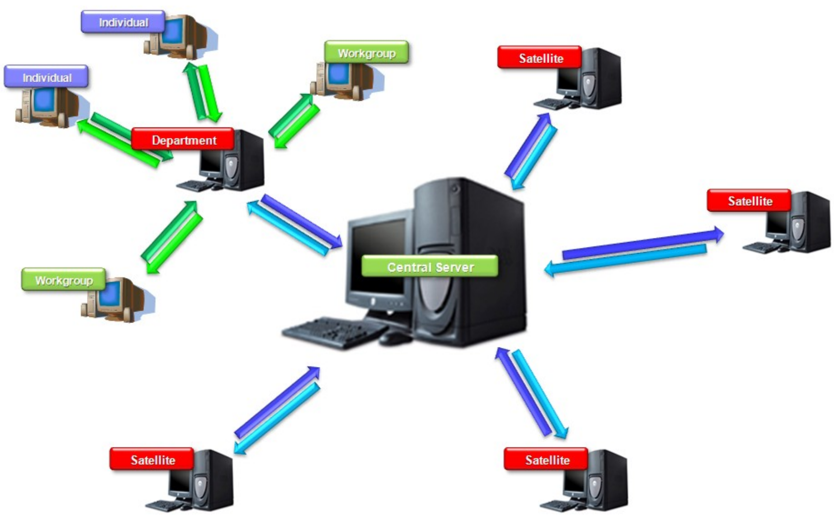

Figure 5 – De-centralization of CAE process workflow

6. JOB DELEGATION

We have already pointed out the need to integrate resources into the CAE workflow management solution. There are a number of items that we can place under resources: equipment, software or a hardware tools, individuals, workgroups, departments or external suppliers and so on. Each of these is capable of performing a specific action within the overall CAE workflow. Naturally, a question rises as to how SPDRM decides to delegate a specific job to a specific resource. Obviously there should be at least a minimum set of rules or criteria onto which the intelligence of SPDRM should base its decision.

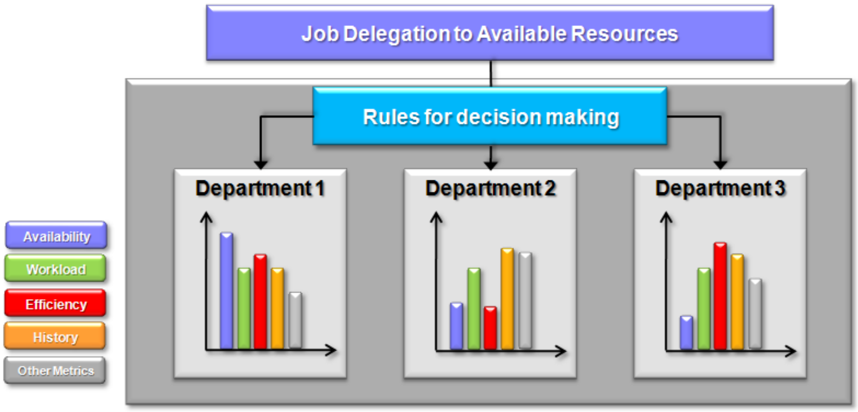

Figure 5 – Job delegation based on decision making rules

Let's see some of these through an example case where three departments are candidates for a particular meshing job (figure 5).

The very first thing that should be checked prior to delegating the job is the availability of the departments at this particular time (maybe one is closed for maintenance or for any other reason). Next, the current workload of the department should be considered, as it may prohibit any new assignments. This also implies that SPDRM has the means to know the current workload situation of a resource and monitor its progress. Moving on, the efficiency of the department in fulfilling similar job is the past is important and can give a clear indication of what and when is to be expected if this resource gets the job.

Another rule to consider is history. This rule relates a particular job to the resource that has carried it out in the past. A typical example can be a mesh improvement job, where in this case the workgroup or department that have created the mesh in the first place are more likely to undertake the quality improvement task. Finally, any other rule that derives from customized and measurable statistics that the enterprise defines can be considered as well. Of course, the reasoning behind the rules that assist decision making in delegating a job is extended to workgroups and individuals, as well as to other non-human resources.

7. JOB DISTRIBUTION, MONITORING AND DATA FLOW

To discuss the issue of job distribution, job monitoring and the flow of related data, we come back to the typical CAE cycle followed within an automotive industry and use as an example the vehicle model assembly process that is distributed to three departments based on the evaluation of workload. Of the three departments, two are considered internal to the enterprise (the Closures and the BIW) and one is considered to be an external Supplier. As shown in the diagram of figure 6, some work is routed to the Closures, a bit more work goes to the BIW and the bulk work goes to the External Supplier.

The first thing these departments will now do is to acknowledge the workload assigned to them. Upon doing so, the related data has to be communicated to the departments in order for each to carry out its assembly work. For the two internal departments the data is available on-line and is transferred directly upon acceptance. Moreover, as these are internal, SPDRM can have a continuous monitoring of their progress. When these departments finish their work, the resulting data are communicated on-line back to the main process.

In the case of the External Supplier the related data have to be communicated through an off-line way (i.e. they have to be packed and sent by email, or placed in a web server etc). Moreover, since this work is carried out externally, there is no continuous monitoring of the Supplier's progress; hence the status changes from 0 to 100% when the Supplier declares that the job is done. In this case the resulting data are communicated back to the main

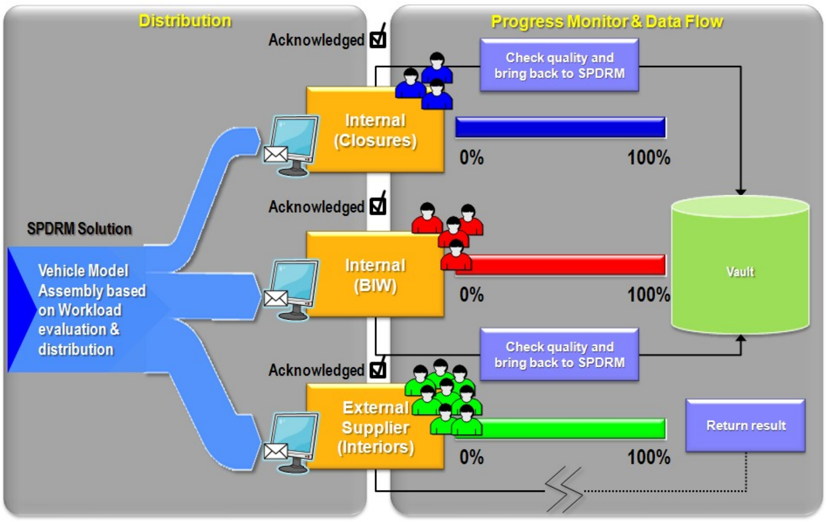

Figure 6 – Job distribution, monitoring and data flow

process through an off-line way and are subsequently reviewed and then brought back into the main CAE process.

8. FUNDAMENTAL TOOLS OF SPDRM

How do we set-up a CAE workflow? How do we monitor its status? How do we identify its bottlenecks and investigate ways to improve it? Response to these questions is given through a set of fundamental tools that SPDRM integrates.

The first tool is the Process Editor (figure 7) which is used by anyone who wants to set-up a workflow. To assist in build-up, a diagram definition tool should provide a simple and intuitive way to combine the fundamental process items. These are: (a) an item that signifies the starting point of the process; (b) an action item that represents a simple action such as 'read a file' etc; (c) a split item that indicates a division of the main workflow in two branches, and a join item that merges branches back to the main workflow. It is noted that split and join items may operate as logical OR-split/join or as logical AND-split/join; (d) the group of actions item representing a lower level sub-process that is integrated into the higher level main flow; (e) the condition item relates the action that must be taken to the value of a variable: for example, you can use variables that are associated with some value like the quality of a mesh; if the quality is good the condition item may point to the end of the meshing process; if the quality is bad the condition item may branch the process and send it back to the meshing department for improvement, thereby inserting an iteration.

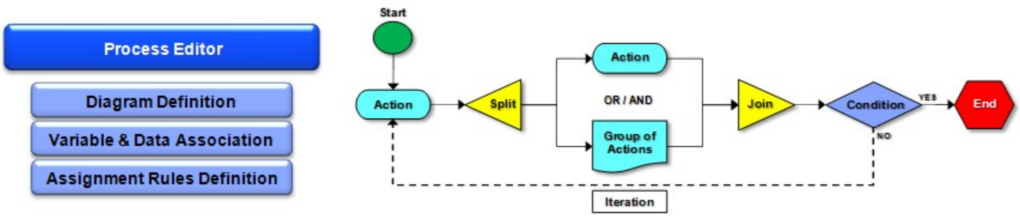

Figure 7 – The process editor

The next tool is the Process Diagram Monitor (figure 8). It is used for visualizing the process at run-time. It displays which actions are completed, which are currently running (with which data, by which resource, to what extend) and which actions are still pending. It also allows real-time intervention so that users can alter the process in order to bypass an unforeseen stoppage or give a workaround to an action that takes too long to complete etc.

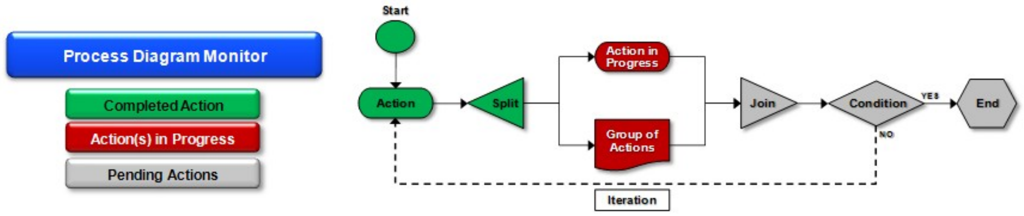

Figure 8 – The process diagram monitor

Finally, a process profiling tool (figure 9) reflects in a graphical form the inter-dependency of process actions against time. It can be seen as a debugging tool that assists the user to identify bottle-necks, investigate parallelization of actions and also investigate ways to reduce the total duration of the process.

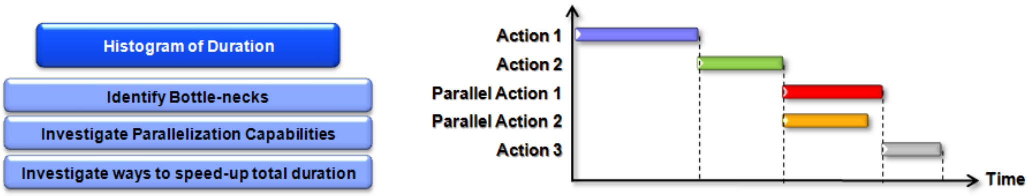

Figure 9 – Process profiling

9. DEPLOYMENT OF SPDRM

Regardless of how good SPDRM is, we cannot expect miraculous results immediately upon its deployment. At first SPDRM should reflect the workflow process that is currently followed within the enterprise. Then, the current workflow should run as is under the guidance of SPDRM for a number of cycles, over which SPDRM collects reliable statistics regarding the sub-processes, the response of the resources, the un-anticipated factors. Finally, with the aid of Process Monitoring, Process Profiling and other, measurable, criteria we identify the bottle-necks of the current process and investigate parallelization of its actions, process restructuring or other alternatives to improve workflow efficiency.

Let us know give an example of the use of SPDRM in a fictional enterprise, starting from reflecting the current workflow used to evaluate a new version of a vehicle. Key players in this scenario are the Model Building Dept. (MBD), the Disciplines (analysts) and of course the CAE Management. Following figure 10, imagine that as soon as the CAD department releases the new version of the vehicle, NVH wants to begin its evaluation and asks the MBD for an NVH model. MBD will have to trim down the original vehicle product structure to an NVH suitable one, translate the related CAD files, mesh with NVH rules and finally assemble a complete NVH model. This model is forwarded to the NVH analysts who subsequently build their loadcases, solve and post-process the results, and finally produce a report for the NVH behavior of the vehicle. This report is submitted to the CAE management which in turn will review, evaluate and possibly suggest modifications back to the NVH team.

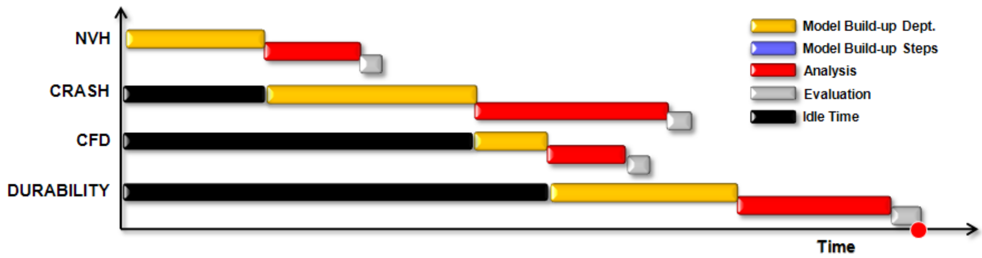

Figure 10 – Profile of conventional CAE work

Similarly, CRASH wants to evaluate the new vehicle as soon as it is released. So they too ask from MBD to prepare a CRASH model, but MBD cannot respond immediately, since it is occupied with the build-up of the NVH model. In this way an idle time is introduced to CRASH, and it has to wait until the MBD completes the NVH model. Of course, when MDB delivers the CRASH model, the analysts can carry on with loadcases, solution, post-processing and reporting to CAE management. Evidently, what we discussed for NVH and CRASH is also true for the CFD and DURABILITY Disciplines who have to stay idle until the MBD completes the models of the previous Discipline.

When profiling the above CAE process it is evident that model building takes too much time and analysts have to stay idle; the order in which Disciplines get their models is wrong, having the less time consuming analyses put first; considerable time difference exists in delivering reports from Disciplines to CAE management, which in turn cannot have the complete picture to evaluate the vehicle promptly and suggest modifications to CAD. By introducing an alternative way for model build-up, based for example on the Common Model Concept [4] and restructuring the process so that the most time consuming Disciplines get their models first, we manage to reduce both idle and total time and allowed all reports reach the CAE management more or less at the same time, so that vehicle evaluation can be based on all aspects. The respective profile is given in figure 11.

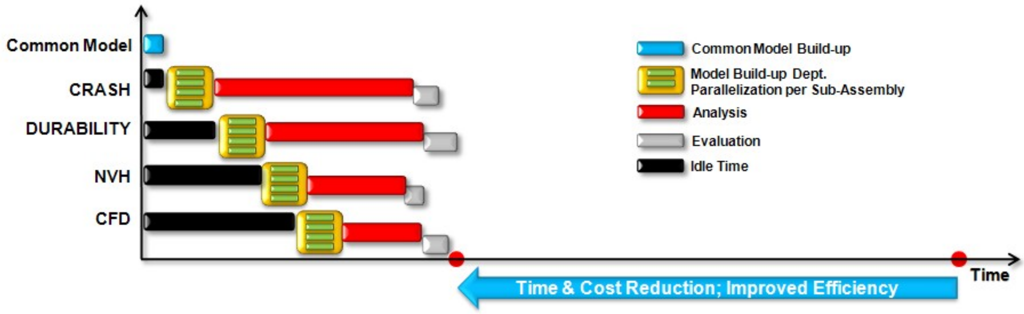

Figure 11 – Profile of an improved CAE workflow

10. CONCLUSIONS – BENEFITS OF SPDRM

SPDRM is focusing directly on integrating enterprise tools and processes, reflecting a deep understanding of the demands of simulation, its role in the enterprise and the knowledge to determine which data and processes belong under formal management and which data and processes should remain ad hoc.

SPDRM couples the enterprise PDM system with the CAE pre-processing tools, by providing the required vehicle product structure (and related data) to the pre-processor and dictating all actions that have to be taken in order to build the desired simulation model. It integrates CAE into higher level business processes and delivers CAE tasks and associated data to analysts, engineers, designers and managers. In turn, these are executed by people and/or applications and can be automated and chained together with the output of one task serving as the input for another.

Deployment of SPDMR will offer significant competitive advantage to engineers, workgroups, departments and ultimately to the enterprise. The anticipated merits are numerous and stem from all aspects of CAE workflow management, such as:

- the overall process consistency and standardization, at all levels
- the harmonization of operations within the enterprise and with suppliers
- the traceability of data, meta-data and their modifications
- the reduction of data redundancy

- the progress monitoring & the effective process quality management
- the reliable and referable documentation
- the productivity improvement thanks to the effective resources management through job delegation to available and competent resources
- the repeatability of processes, even when using updated or different datasets and software tools
- the quality improvement of the deliverables
- the management of simulation generated intellectual property
- the increase of confidence to CAE with parallel reduction in time & cost of the overall simulation process

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