Collaborative Product Development in a Distributed Engineering Environment

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Das Management einer unternehmensübergreifenden Produktentwicklung stellt erhöhte Anforderungen an die Kommunikation zwischen beteiligten Partnern und an die Transparenz der dafür notwendigen Daten. In diesem Artikel wird zum einen eine Lösung des Kommunikationsproblems in Form eines parameterbasierten Engineering Workflows vorgestellt. Zum anderen wird ein Konzept eines Collaborative Workspace dargestellt, welches eine sichere, webbasierte gemeinsame Datennutzung ermöglicht, sowie den Datenaustausch erleichtert.

This paper presents a concept to improve the management of collaborative product development in a distributed engineering environment. A product data driven workflow as a key enabler will be shown, that is able to manage engineering tasks across company borders. Furthermore, a concept for a secure web-based workspace will be given, that enables partners to share and exchange product data. This paper is based on the interim results of the European research project SIMNET – Workflow Management or Simultaneous Engineering Networks /1/.

1 Collaborative Product Development Demands Better Access to Product Data

Only a small time share of engineering working hours can be considered 'productive'. Almost 25% are consumed while waiting for decisions or searching for information. In addition an overload of information has to be checked daily, such as notifications about proposed changes in products. The amount of information is increasing even more rapidly when working in a distributed environment where multiple partners have to work together on a complex product. Product modules not directly related to core competencies of a company are developed and delivered by suppliers and engineering partners using their know how and resources. Still time and budget is wasted because of work on outdated or obsolete information due to a lack of transparency and communication.

In order to shorten the time for development and to decrease the number of loops in the development process all partners have to work together from the early stages of product development. This leads to increased needs to exchange and share important

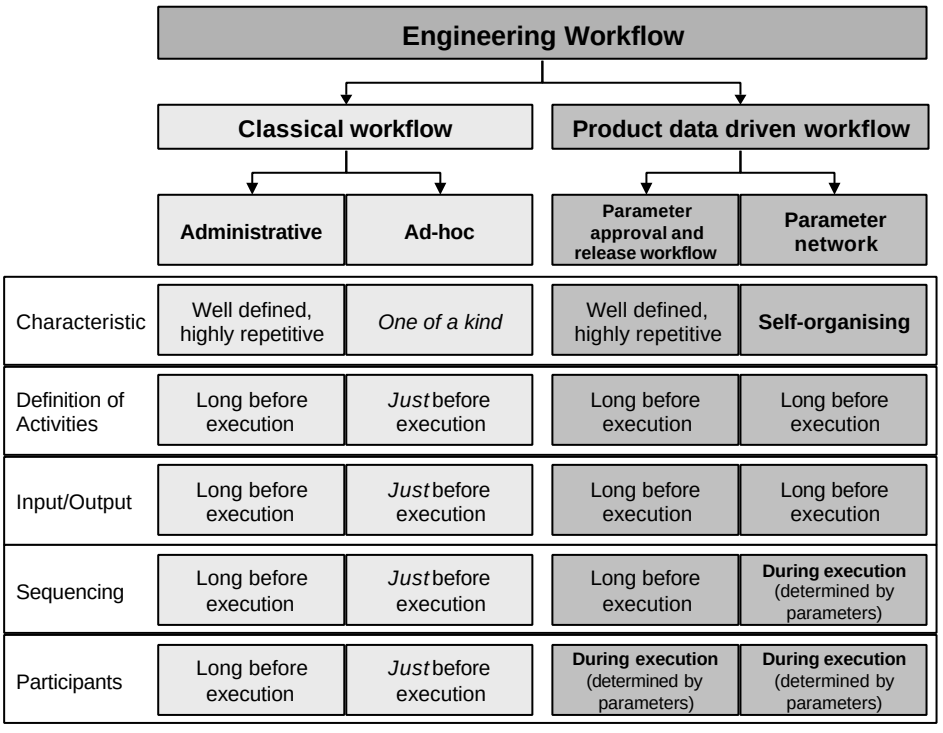

Figure 1 Engineering Workflow – an Evolutionary Step beyond 'Classical' Workflow

and correct information among partners.

Today's product data management (PDM) systems provide powerful functionality regarding the management of complex product data. However, most often such systems are focusing on a single company-centric solution, not taking into account the variety of systems used at partner sites in the supply chain. One can easily imagine problems regarding the interoperability when starting to cooperate with partners.

Duplication of data on different sites or to a central data repository might be a solution. However, it does not overcome the problem sufficiently because still consistency of data can hardly be ensured. Furthermore, a solution supporting engineering activities across company borders is required, that facilitates the communication between the different partners.

2 Parameters – Key Enabler for Product Data Driven Engineering Workflows

Within the SIMNET project the workflow management functionality of a state of the art PDM system has been improved towards an engineering workflow system supporting the engineering cooperation within the supply chain. Within the context of SIMNET the following definition of an engineering workflow can be given (**Figure 1**):

Engineering workflow consists of a combination of 'classical' and product data controlled workflow, where the 'classical' workflow reflects document based administrative and ad-hoc workflows (e.g. ECR/ECO[1] based engineering change procedures), while the parameter controlled workflow consists of parameter based approval and release procedures as well as activity routing by means of a parameter network. /2/

Parameters describe attributes and properties of product components as well as relations between them along the life-cycle of a product. Three different categories of parameters can be determined:

- functional parameters (e.g. engine power),
- geometrical parameters (e.g. length of a shaft) and
- material related parameters (e.g. steel number).

[1] ECR – Engineering Change Request, ECO – Engineering Change Order

The approach is based upon observing how engineers think about their tasks. Documents or procedures dedicated to product development are not their primary focus. They view their work as making engineering decisions. These decisions are reflected in determining or changing engineering variables – the parameters. Parameters represent the specific circumstances in a given engineering situation. Parameters often share complex relationships which can be represented in terms of equations, for example:

Max_axle_diameter = f (maximum_axle_load, bear_distance, track_gauge, axle_material)

Due to the large amount of possible parameters needed to describe a product completely, it is vital to concentrate on the most important ones. Only a subset of parameters is required to enable a sufficient collaborative product development. Such subsets consist of system and interface parameters which have an impact on the work of more than one company of the supply chain. The core elements of the parameter management are:

- the definition giving the name and the physical unit on a project independent base to facilitate their reusability,
- the instance with the latest value, status and hardness grade for a given project,
- user categories that define the role of a stakeholder of a parameter, and
- an approval and release procedures enabling a sufficient communication between stakeholders of a parameter.

As different people in the supply chain decide on or use parameter values, capturing their interest on a parameter consequently specifies the relationship between the decision-making people and therewith the required interaction of a main contractor with his suppliers and engineering partners. In order to classify the different decion-making people a concept of five user category is used:

- Co-ordinator – technically responsible for a parameter,
- Collaborator – involved in the creation and elaboration of a parameter value, participates actively in the approval workflow,
- Reviewer – whose work is affected by a parameter value, participates in the approval workflow, but silent approval might be sufficient,

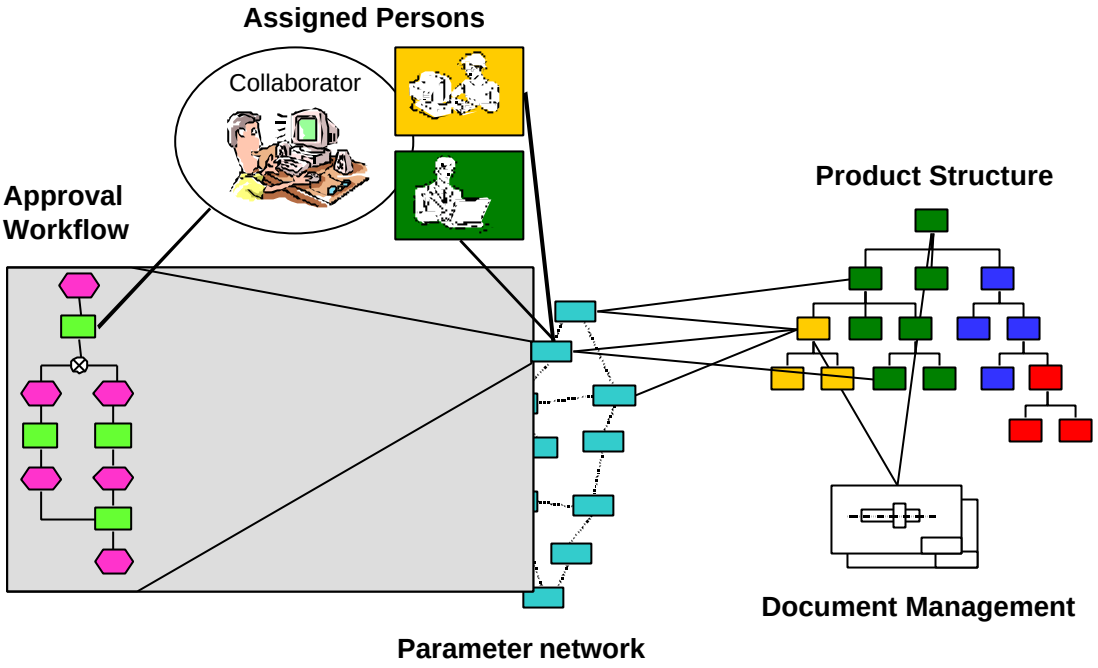

Figure 2 Integrating the Parameter Management into PDM Core Functions

- Subscriber – interested in a parameter, gets a notification only during approval workflows,
- Supervisor – responsible for a parameter from the organisational point of view, has to release a parameter depending on the status of the overall project.

On the other hand the user categories determine the participants of the approval and release workflow during its execution.

Figure 2 illustrates the overall context of the parameter-based approach and its integration into the core functions of PDM systems. Starting point is the product structure with allocated documents that describe parts of the hierarchy from different views, such as a CAD drawing or a FEM model.

By capturing system and interface parameters and their linkage to affected components of a product structure indirect interdependencies between product components are revealed. The evolving parameter network furthermore indicates the relations between different parameters. Thus enables an easy detection of affected product components whenever a change request occurs.

People that have an interest in a parameter are assigned to it within a certain user category that meets their level of interest. This assignment may change from one parameter to another, for example an engineer designing the brake equipment for a train might be co-ordinator for the parameter 'hydraulic pressure' while at the same time he is a reviewer for the parameter 'maximum train speed'.

Furthermore, one approval and release workflow is applicable to all parameters. Participants of such workflow are determined by allocating the corresponding user category to the workflow tasks. Once the workflow is started for a given parameter the people assigned to that user category are determined as workflow participants for this parameter.

When introducing this approach an analysing phase is required to capture the most important parameters and to create the parameter definitions accordingly. Starting the implementation together with a pilot project enables engineers to create the parameter definitions and instantiate them simultaneously. The relations between the parameters are captured during the performance of the engineering activities.

Change requests are usually communicated in a parameter-based way. Examples are "The engine power needs to be increased" or "The shaft diameter is not sufficient". The parameter to be changed then automatically becomes the starting point for all further considerations.

As soon as a parameter is subject to a change, its current status is set to "in change". This is also true for the linked product structure items and related documents. Afterwards only those persons (or roles) are informed which are assigned to

- the changed parameter itself and

- all adjacent parameters (parameters which show a first-degree interdependence with the changed parameter).

The notification of the change is performed independent from the persons' company affiliation.

However, the system only highlights the existing relation and the possible change propagation between the changed and the neighbouring parameters in the network. The notified persons must jointly clarify whether “their” parameters are actually affected by the change. As long as this clarification is not completed, the neighbouring parameters remain in their current status.

As soon as it becomes clear that an adjacent parameter is affected by the change, its status is set to “in change” as well. In addition, the persons assigned to parameters with a second-degree relationship to the initially changed parameters via the affected one are notified.

The objective is to cope successfully with the change propagation through the product model by means of a step-by-step identification via the parameters and subsequent interaction of all people assigned to the (possibly) affected parameters. As soon as the change propagation is clarified to its full extent and a consensus between all people involved is reached, all parameters set to “in change” during the change process will be jointly set to “in approval” and finally approved as well as released within a single parameter-based approval and release workflow.

The approach described in the previous section has been implemented as a prototype into the PDM system axalant™ of EIGNER + PARTNER AG. The parameter management is deemed to be applicable to business fields that are dealing with small and large scale series and platform concept, such as automotive industry and tool manufacturing. The effort of capturing parameters and their relations wont pay back for one-of-a-kind products.

3 A Distributed Workspace to Enable Engineering Processes Across Companies

During the last years tremendous efforts have been spent to shorten the throughput time in production. Now these efforts are extended to the development stage of a product, which offers great potential to improve efficiency. Simultaneous engineering has been deployed in companies to overcome the time consuming sequential way of working. Experts from other disciplines are integrated into a concurrent engineering design team. PDM and ERP systems providing workflow management capabilities support such teams by enabling the exchange of information. However, so far the IT support ends at the borders of each of the involved companies.

The presented parameter approach significantly improves the communication within the supply chain. It makes people aware of the consequences of changes and indicates who needs to be included into a discussion. However, so far it is a more process oriented solution. The available prototype can be used as stand alone application supporting the described engineering workflow. Partners without a PDM system and/or without parameter management could be included in the PDM system of the main contractor. Work requests are sent out to their mail boxes with all the required information in it. Approval or disapproval could be stated either by an ‘accept’ or ‘reject’ button within the email, that creates a reply automatically, or by including a hyperlink that leads to the web-interface of the PDM system where additional information can be retrieved.

However, such solution would only support the view of the main contractor of the supply chain. It does not support the linkage of partner information to the overall picture of the product, because it does not enable real information sharing.

3.1 How to share information in a distributed environment?

Depending on their know-how partners are developing product components and modules on their own and within their local systems, only following the specification of the main contractor. In an ideal world the specification would be mature right from the beginning and the component delivered by the supplier fits perfectly into the final product. However, practice shows that this case never occurs. Changes to the specification are required from the main contractor side as well as from the suppliers side as the design evolves. Both partners need to share a common view on the information relevant to both of them.

Currently, there are two different ways to enable access to data that is used by different partners. The first way is to grant access to the host system of one of the partners. All other partners are forced to use the client of this specific PDM system or to stick to the web-interface which is most often re-

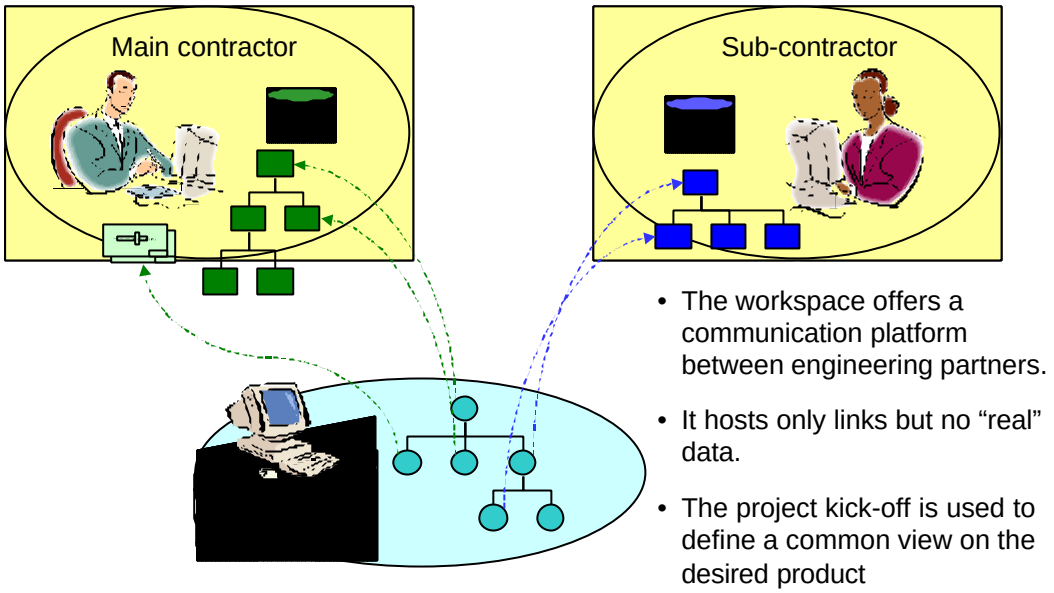

Figure 3 The Distributed Workspace

duced in functionality. However, the number of required clients increases according to the number of different PDM systems used by the partners. Since all data is managed only in the system of the main contractor reusability of data is nearly impossible for supplying partners.

The second way would be to use an interface between two systems and to replicate data at certain points in time to enable access to common data. In this case it is nearly impossible to ensure consistent data, because modifications may occur on both sides. In addition, it requires n*(n-1)/2 interfaces to connect all partners of the engineering team. Therefore, other concepts are required to enable real concurrent design across companies taking into account the security demands and intellectual property rights of all partners of the supply chain.

In order to fulfil such requirements the concept of a distributed workspace has been developed within SIMNET. Such a workspace is used to publish data in a controlled way. Publishing in this context means the creation of a node in the workspace that represents a link to a remote object at a partners site (see **Figure 3**). Therewith no “real” data is stored in the workspace itself.

The workspace provides a virtual engineering community (VEC) with a platform that allows a secure sharing of information and a centralised management of project dependent data, that is considered relevant for the organisation and control of the co-operation within the community, such as notification procedures and administrative information about users. It allows all partners to get an instant look on the current stage of a project and the data that is available, while at the same time each partner controls the access to his data individually.

Within the workspace users are able to navigate through the data in a way that is independent from the current location of the data. Detailed information can be retrieved by following the link to the remote object at the partner side, that owns the data. Furthermore, the distributed workspace provides notification capabilities that can be used to inform users about updates of nodes.

In addition special nodes are used to represent system and interface parameters in order to manage projects based on cross-company engineering workflows. Such nodes are linked to all representations of the parameters stored in the local PDM systems of the partners.

3.2 Requirements and Demands regarding a Distributed Workspace

Sharing and exchange of product data across company borders strikes a very sensible area within a company. Knowledge and information are treated as very valuable goods that require special protection. Therefore, special attention will be put on security issues in terms of:

- granting access to data only for authorised personnel, that includes ensuring that a person can be clearly identified and
- secure data transport independent of the way the data has been accessed (using a web-client, a native PDM client or email).

Since access rights to the local data are granted at partner level each partner is able to monitor at any time who accessed what data at which time. Furthermore, this access can be revoked at any time if contractual problems or abuse of data occurs, without the need to ask a third party to shut down the access.

Another aspect is related to the parameter management itself. Since the concept presented in section 2 leaves a lot of possibilities of usage, the mechanisms used in the Workspace must not affect the implementation of each company. Partners only have to agree on a common strategy used within the workspace. That means local approval procedures and life-cycle definitions are not affected so the engineers can stick to their normal way of working. Mapping mechanism need to be implemented in the workspace to ensure at this level a common understanding of statuses and procedures.

3.3 Deployment of the Distributed Workspace

During a kick-off meeting at the beginning of a project the partners need to define their common view on the desired product and the information that needs to be shared. Later on each partner links his information to the corresponding nodes. The evolving structure does not necessarily match the real product structure. It is more a work break down structure or project view on the product.

The distributed workspace is a server on its own that can be hosted by a service provider. Companies with multiple supplying partners are able to create a workspace for each project they are working on. All project participants are able to access the workspace using a web client. Using the distributed workspace as a central gateway to project relevant data enables efficient handling of information.

A user requests data via the web client. The login procedure is based on a public key infrastructure (PKI) that clearly identifies a user. If access to the workspace is granted the user may navigate the current node structure. If detailed information are required on a special node the workspace sends a request together with the login information of the current user to the web-interface of the local PDM system. There the local access rights are checked. If access is granted the data will be presented in a browser window (see **Figure 4**).

Applying the parameter approach as presented before, enables engineers to track the ongoing product development from one location. All requests for approval are directed by the Workspace to the in-box of the user. In case of a change within one system a notification is passed to the workspace which in return sends notifications to the other affected systems that host a representation of the modified parameter. Within the local systems approval workflows are executed depending on the partners' demands. The results are exchanged via

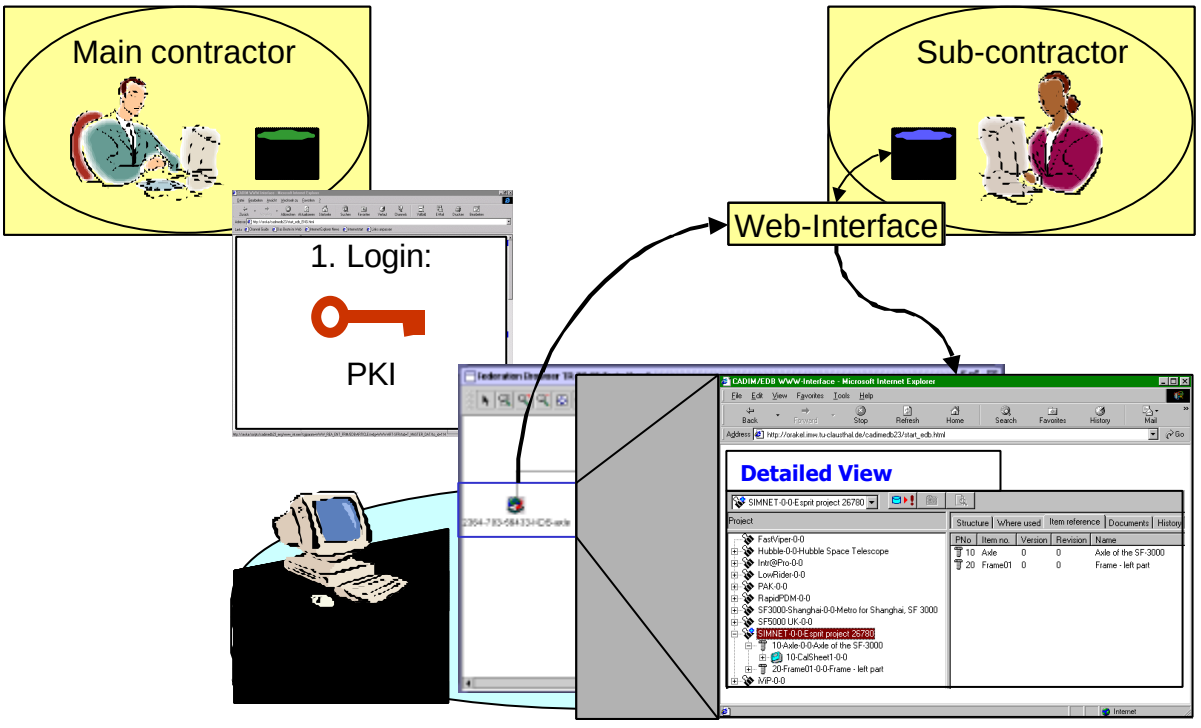

Figure 4 Retrieving Data via the Workspace

the workspace which ensures the required synchronisation. /3/

A summary of information of a parameter is presented in the workspace, such as latest approved value and current state. This is especially useful if partners do not have a parameter management on their own. In this case a subscription mechanism can be used to keep them informed about the ongoing elaboration. Approval results are handled by the workspace to keep in sync with the overall approval procedures.

During the runtime of the SIMNET project a distributed workspace will be developed based on an axalant™ server that hosts project relevant data regarding the notification mechanism and links to original data of the partners systems.

3.4 Security Mechanisms deployed in the Distributed Workspace

The distributed workspace is based on the interconnections, through the internet, of the participating organisations. Within such a *Trusted Virtual Community*, the full spectrum of security services – encryption of messages, authentication of users, authorisation of services, integrity and non-repudiation of messages – is required for online interaction (e.g. web) and offline message exchanges (e.g. email).

The SIMNET security solution is based on state of the art standards – PKI (Public Key Infrastructure), TLS (Transport Layer Security) for online interaction and S/MIME (Secure Multipurpose Internet Mail Extensions) for email – and additional functionality. Strong security is provided through 128+ bit (symmetric keys) and 1024+ bits (asymmetric keys) ciphers.

All the partners of the *Trusted Virtual Community* are peers, with the exception of a *Management Entity* (ME) that is independent from any single organisation and is trusted by all the members of the virtual community. The role of the ME is to implement the security policies decided by the community and make sure that the security is correctly enforced, while preserving the autonomy of the members (e.g. with regards to the "visibility" of the data); the ME is also the CA (*Certification Authority*).

The identification of users, their roles and privileges within the community, and their *Public Key* are managed by a Directory Service, based on the LDAP standard, distributed among the ME and the members. The portion of the directory service under the control of a specific organisation manages the local authorisation rights. Smart cards will be used to reinforce the security.

The deployed security mechanisms are used on one hand to determine access rights while a user is browsing through the workspace and on the other hand to prove the correctness of data by checking its digital signature. Therewith, the user can only see what is allowed by the assigned permissions. In addition, the access rights define whether a user is allowed to follow a link into the partner's database and/or to download files represented by nodes in the workspace. Furthermore, the access rights determine which elements can be created, updated or deleted and what relations between nodes can be established.

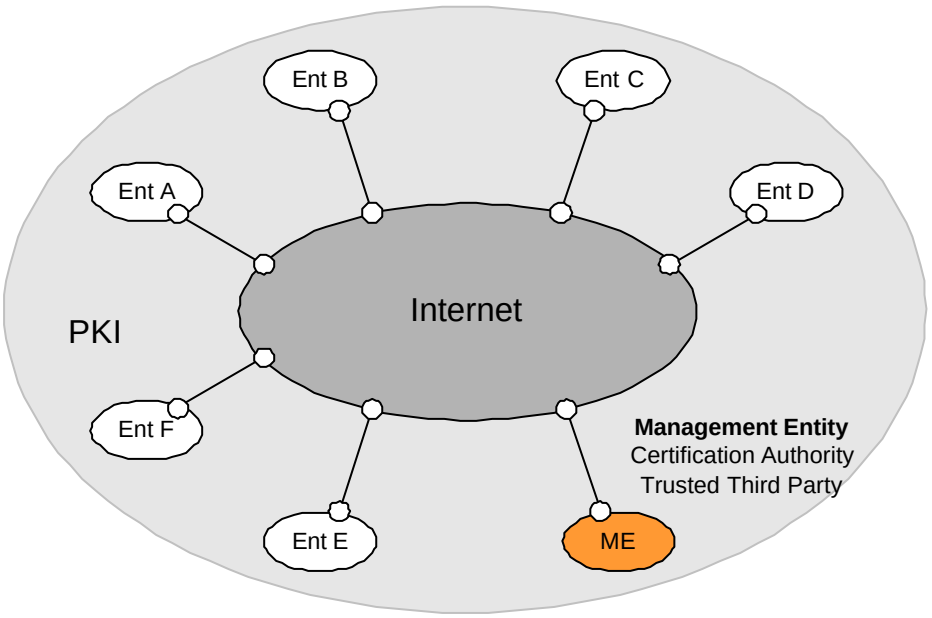

Figure 5 Security Infrastructure /4/

Digital signatures are used to prove the correctness of links (avoiding guessing of links to other objects, that shall not presented in the workspace) and the original author of a link. Thereto, the signature is made up of identifying attributes of an object and of the authors specific key whenever a user publishes objects stored in the partner's database. Only with

this key objects can be retrieved from a partners database via the workspace, as shown in **Figure 5**. /4/

4 Conclusions

Today, the IT support for inter-company teams developing a complex product is limited to a "reactive" file exchange or access to a central PDM system. The presented parameter approach adds a "proactive" aspect to virtual engineering communities. Whenever a parameter of common interest in the supply chain is generated or changed, the presented solution not only identifies the need for communication, but also triggers the communication in terms of notifying affected people independent from their company affiliation. Parameter-based approval and release procedures logged by a PDM system guarantee the necessary quality assurance even though documents (such as ECR and ECO) are not involved.

The presented architecture for a distributed workspace enables access to data needed to execute engineering tasks, even if the data is stored outside the company. The data is protected by state-of-the-art security mechanisms. In addition, the workspace provides communication and a document-free quality assurance in a distributed engineering environment.

Major benefits of the shown approach are:

- improved quality of engineering results, due to a better information base
- shortened throughput time regarding the product development and engineering change management,
- improved co-operation across company borders and
- enabling of an easy and secure access to data within a virtual engineering community.

The actual potential will be identified during the upcoming months by testing the prototype in the end-user environment of the SIMNET project.

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For further information please check out the SIMNET web-pages *http://www.imw.tu-clausthal.de/simnet.*

6 References

/2/ Rouibah, K.; Schmitt, R.; Caskey, K.; Goltz, M.: The SIMNET parameter based approach eases inter-company engineering change management; published at the International Conference on Concurrent Enterprising, Toulouse, 28-30 June 2000

/3/ Goltz, M.; Schmitt, R.; Product Data Controlled Engineering Workflow in the Supply Chain; Proceedings of the ProSTEP Science Days 2000; Stuttgart; 13./14. September 2000

/4/ Goltz, M.; Schmitt, R.; Vanden Bossche, M.: Managing the Development and Engineering Changes of Complex Products in a Distributed Engineering Environment; E-business: Key Issues, Applications and Technologies; IOS Press 2000