Design and logistics IT federation through Product Lifecycle Support standard

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Abstract: Wide diffusion of methodologies and software relevant to Product Lifecycle Management (PLM) in industrial companies faces heterogeneity of IT systems. Especially, the lack of interoperability between Product Data Management (PDM) systems, that drive virtual product development, and Enterprise Resource Planning (ERP), which manages real product, cannot lead to a coherent description of the product development process. We show that a "mediator" approach is pertinent for the coordination of these two systems. The use of open standards, and more precisely STEP Application Protocol 239, known as Product Lifecycle Support (PLCS), allow overcoming issues related to semantic part of this interoperability. The last part of the paper focuses on preliminary works in order to develop a product model, coherent according to the design or production viewpoints, for a specialization of generic PLCS data model and a future implementation.

Keywords : PLM, interoperability, PDM, ERP, PLCS.

1 Introduction

The current trend of complexification in the development of new products in industrial companies leads to many issues. Complexification is intended here as the multiplication of partners (subcontractors, suppliers, customers located all over the world), the stronger integration between the actors of a project (design, production, marketing, maintenance etc.) as well as the huge amount of data produced, exchanged and stored during the development phase.

Furthermore, although the economical environment is very constraining, the main goals remain to reduce the time-to-market, the costs, and improve the quality of the product. In this paper, we focus on companies in the field of aeronautics and defence industry, which can be characterised by the fact that:

- the products (aircrafts, military vehicles, satellites) have a long lifecycle (up to fifty years),
- they evolve in a context of strong regulation (security, traceability, long term data retention),

- these complex products require the participation of many specialized companies, some of them being considered as small and medium business enterprises,
- according to the nature of the project, many new partners may be included in the project team,
- some major companies can acquire other companies to get specific technologies,
- the IT system is highly heterogeneous due to economical or historical reasons.

The IT that drives the product related data from design to retirement is then a strategic tool. The industrial deployment of this IT must satisfy the need of three main actors:

- the design engineer, maintenance operator, manufacturer, salesman, must be insured that the coherency of the product data for its whole lifecycle,
- the IT manager must ensure the flexibility and the agility of the IT architecture, to allow quick and efficient integration of third part IT from another partner,
- the head must reduce the total cost of ownership (TCO) of the IT, TCO including initial investment as well as maintenance.

In such industrial companies, the choice, deployment, use and maintenance of an efficient IT must then associate these entire actor. In a few words, the systems composing the IT have to interoperate at the lowest cost and with the best quality, i.e. ensure product data coherency. However the dispersion of information over heterogeneous models requires new solutions to preserve the overall coherence of the company information system [1].

The purpose of this paper is to demonstrate that the definition and the deployment of an industrial IT architecture as well as a suitable product model are closely related to each other. The exclusive focus on one or the other point fails to achieve both goals previously mentioned. As a consequence, the paper is organized according to these two viewpoints: Section 2 introduces interoperability general statements and the need of standards. Section 3 then discusses the different systems used in design or logistics activities and a possible IT architecture. Section 4 deals with the semantic issue of product representation and the way to solve it using the STEP standard. Section 5 is then a synthesis of these last two sections, and proposes a possible framework to achieve PDM/ERP interoperability. Section 6 concludes this work with the further work required for implementation issues.

2 Interoperability and standards

According to the surveys of Kosanke [2] and [3,4], five different definitions of interoperability can be found. However, in the following of this paper, interoperability will be defined as the ability of two or more systems to exchange information and have the meaning of that information accurately and automatically interpreted by the receiving system. This definition is the more adapted to the issue presented since it merges the technical and semantic concepts of interoperability.

When analyzed from the IT viewpoint, these close concurrent definitions can be merged in a multi-level interoperability approach [5]. There are several levels of interoperability that must be completed in order to make an exchangeable representation understandable by two different systems:

- encoding: segment the representation in characters,
- lexical: segment the representation in words,
- syntactic: structure the representation in sentences,
- semantic: construct the propositional meaning of the representation,

- semiotic: construct the pragmatic meaning of the representation, or its meaning in context.

This typology can be compared to [6], which define three different levels for interoperable enterprise systems:

- technical level: data and message exchange,
- semantic level (i.e., information and service sharing),
- organizational level (i.e., business unit, process and people interactions across organization borders).

Considering products with long lifecycles, it's necessary to ensure the product data coherency over decades. As a consequence, the product description must be robust whenever a change occurs in the enterprise organization and/or business processes. Due to the dynamic property of economical environment, these processes may be volatile whereas product information must remain stable. Baïna *et al.* [7] introduce the concept of 'product-oriented interoperability', *i.e.* the ability of different enterprise systems to manage, exchange and share product information in a complete transparency to the user. In that sense, the enterprise system interoperability problem solving must be driven by the semantic level, that is, the product representation.

The use of standards is underlined in the literature as a way to overcome technical issues in the interoperability field. According to [8,9], enterprise interoperability requires a fair amount of open standards to be able to share and exchange information in a distributed organizations and heterogeneous computer environment.

There are also economical arguments in favour of standards. The American National Institute for Standards and Technology (NIST) [10] identifies three costs of interoperability: avoidance costs, migration costs and delay costs. The NIST estimates that the use of the STEP [11] standard has the potential to save up to one billion dollars per year by reducing interoperability problems in the automotive, aerospace, and shipbuilding industries.

General arguments of §2.1 and §2.2 are specialized for the need of PDM/ERP interoperability (*cf.* §3). The technical and economical considerations of §2.3 lead to investigate the STEP standard as a possible way to be the basis of the 'product driven interoperability' (*cf.* §4) approach.

3 Design/Logistics IT interoperability definition and needs

3.1 Design and logistics tools

The product design process is structure about two families of systems: authoring tools and Product Data Management (PDM) systems. Authoring tools are relevant to creation/modification of design documents: 3D MCAD, ECAD, requirements etc. All these authoring tools are providers of data for the Product Data Management (PDM) system. The PDM system is designed to manage product design data lifecycle.

A Product Data Management Tool must have the following features [12]:

- the exhaustive list of parts that compose the product,
- parts and documents maturity state management,
- integration with authoring tools,
- product breakdowns and multiview access (as-designed, as-built, as plan, as maintained)

However, PDM system is not intended to manage spare parts neither physical parts (nor parts as individuals).

On the logistics side, Enterprise Resource Planning (ERP) systems are dedicated to sourcing logistics, maintenance, orders/service forecasting, production planning. ERP is not suitable for access design information, or to organize or structure the design process. There is however a narrow link between what has been developed during the design phase and how it is produced [1] and thus a deep relationship between the systems dedicated to each of these phases: they must interoperate to enable information exchange between the design and production. Unfortunately there is no native integration or interoperability support between PDM or ERP commercial products, although the needs expressed by end users are well known: engineering bill-of-material (EBOM) to manufacturing bill-of-material (MBOM) bidirectional conversion, inventory level accessibility for designers, access to design information for maintenance operators and As-Maintained/As designed issues [13]. The initial step to ERP/PDM integration can then be to build a semantic bridge between PDM parts/product breakdowns and production management concepts related to Material Requirement Planning (MRP) such as bill-of-materials, routings and work centers.

3.2 Interoperability attempts in the PLM field

The literature gives examples of interoperability involving PDM or ERP systems. The main interoperability issue in the design phase seems to be the CAD/PDM integration [14, 15, 16]. There are also a few works related to ERP/MES interoperability (see for instance [7]). However, according to the state of our work, it appears that the PDM/ERP interoperability field is still opened. These two families of systems involve people of different cultures that do not share the same semantic view of the product: while designers work to define a virtual product (i.e. a representation of the product using digital information) that fit the requirements, logistics focus on the real product considered as a the incoming/outgoing piece of a set of time based activities (cf. fig.1). This semantic issue is here considered as the major issue to solve in order to achieve PDM/ERP interoperability.

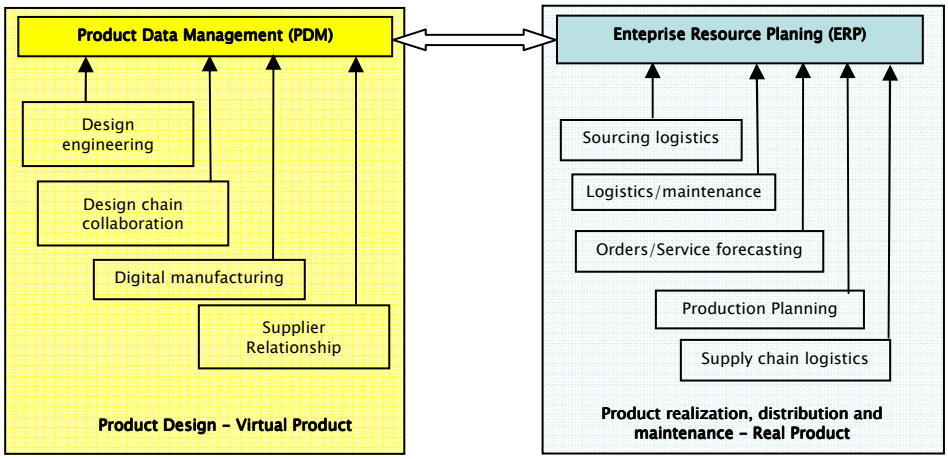

Figure 1 The need/lack of a PDM/ERP interoperability

3.3 A mediator based interoperability architecture

When attempting to implement interoperability between two systems without changing them, two different approaches can be listed: a point-to-point integration or an Enterprise Application Interface (EAI) based interoperability. Assuming a set of 2n systems to connect, point-to-point integration requires a number of translators equals to 2n(n-1). This is thus unacceptable in terms of software development and maintenance costs [14].

The EAI solution, i.e. a central subsystem responsible for the communication between all other systems, is pertinent from an economical viewpoint since the number of required translators decreases to n. This approach has been recently extended by the 'IT mediator' concept [17]. Assuming the systems are Service Oriented Architecture (SOA), the mediator organizes data conversion, process orchestration and application management. This hypothesis is here validated since current trend is to make commercial products become SOA based (for instance TeamCenter, Windchill, SAP, Adonix, MatrixOne etc.), and this approach is a possible and efficient way to consider PLM interoperability in general and design/logistics in particular.

The upcoming 2.0 release of the OMG PLM Services offers a wide range of available services in the field of PLM: part identification, product structure, documentation management, shape/transformation, classification, properties, alias identification, authorization, configuration management, change and work management, process planning and a multi language support [18].

The product structure interchange and conversion part of this mediator is the core of this study. The next part of the paper (*cf.* §4) explains how the use of standard can lead the work related to this topic.

4 Product model driven interoperability using Product Lifecycle Support standard

4.1 Standards in PLM

In a recent survey on standards in PLM fields, Rachuri et al [19] propose a four-level hierarchical typology of standards:

- Type 0: standards for implementation languages,
- Type 1: information modelling standards (like EXPRESS, UML, XML for instance),
- Type 2: content standards, domain of discourse: product information modelling and exchange standards (STEP), information exchange standards, product visualization standards, e-business and value chain support standards, security standards,
- Type 3: architectural frameworks standards.

In a product-driven interoperability, we focus on the Type Two standards. According to this typology, the authors map the scope of the major current Type Two (content) standards of the PLM field along two dimensions (product's life cycle major stages or phases, complementary aspects of the information). They conclude that there is no standard that provides full coverage of the PLM support spectrum because it is fragmented, incomplete in coverage and the limited domain of discourse adopted by the vast majority of Type Two standards for content (*cf.* fig. 2). Considering the

design/logistics interoperability context we focus in this paper, it is clear that there is no intersection in the Design/Production/Supply area that could lead to coherent product representation. In the next subchapter, we focus on the way to overcome this issue.

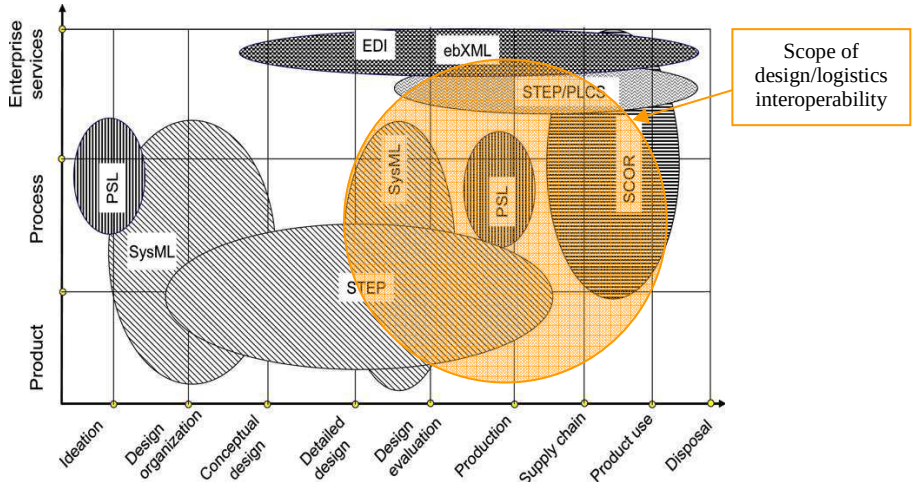

Figure 2 Rachuri *et al.* PLM standards 2D map

4.2 The ISO 10303:239 or Product Lifecycle Support standard

The international standard ISO 10303 [11] known as Standard for the Exchange of Product model data (STEP) covers computer-interpretable representation of product data, and its exchange. The objective of ISO 10303 is to provide a means of describing product data throughout the life cycle of a product that is independent from any particular computer system [20]. The really first STEP developments were lead by CAD data representation and exchange. STEP became after that a suite of specific content standards known as Application Protocols (APs). At that time, STEP coverage scope is wide, but does not permit to describe the whole lifecycle of a given product. It only allows to structure specific industrial environment around one activity or product typology.

Two events then occurred in the early 2000's:

- In 2002, the STEP PDM Schema [21] was released. It is a core set of entities in STEP that support the mapping of concepts for Product Data Management (PDM), and built as a subset of APs 203, 214, 212 and 232. It's the first attempt of merging product semantics and data model from these differents APs.
- In 2005 is published the AP239, known as Product LifeCycle Support (PLCS) [22]. PLCS is the first STEP Application Protocol addressing a wider scope than other APs and also a generic and extensible product data model. This AP is thus discussed in detail in the next subchapter because identified as a way to merge design and logistics semantics.

AP239 propose a framework for the integration, exchange and management of technical data necessary for the support of a complex product and its evolution along its whole lifecycle [23]. Its rich semantic offers information model required to define a complex product and its support solution, to maintain this product, and describe configuration change management of a product and its support solution.

PLCS is structured around the concepts of 'product' and 'activity'. In the PLCS semantics, a product can either be a product existing in the real world, a product that may come into existence as a consequence of some realization process, or a set of functions. As well, an activity is defined as the occurrence of an action that has taken place, is taking place, or is expected to take place in the future (change, distilling, design, a process to drill a hole are example of activities). PLCS data model then includes following descriptions:

- representation of product assemblies, product through life and product history. This representation is based on the PDM Schema,
- specification and planning of activities for a product, representation of the activity history of a product.

These ISO 10303 statements lead to two observations for our purpose:

- in the fig.1, the small axis of the ellipse representing PLCS location in the (lifecycle, PPE) referential should be longer, since PLCS includes a rich data model for product representation,
- The scope of PLCS seems *a priori* suitable for PDM/ERP interoperability: the product representation, build upon the PDM Schema, match the PDM semantics whereas the activity model adds a temporal parameter that makes possible the description of design processes, manufacturing processes or routings. However, figure 2 shows that PLCS is limited in scope to the 'enterprise services' representation.

PLCS aims at covering a wide lifecycle state of the product (from design to disposal or in service use). Aware that it would be impossible to fit all the specific needs of potential PLCS users, the project team designed PLCS as en extensible standard [22]. PLCS thus offers a generic data model that it's possible to specialize, under the condition of a methodology conformance, for specific business domains. This specialized data model is released in a Data Exchange Set (DEX) [24] that defines how to use it. The OASIS consortium is responsible for the development and standardization of these DEXes.

4.3 A graphical representation of PLM standards

The attempt of Rachuri et al [19] to map PLM standards to a two dimensional chart misses the fact that PLCS provides an extensible generic data model. This extensibility can be regarded in an other dimension related to business domain. A 3D map representation of STEP standards is proposed (cf. fig.3), along the three following dimensions:

- lifecycle stage (LC): APLC focus on lifecycle stage (design, manufacturing etc.),
- granularity: some AP offers a more detailed product representation than others. Regarding all STEP AP, the wider is the scope, the less granular is product model,
- business domain (BD): APBD cover specific business domains like automotive industry or ship building.

This representation shows that the PLCS data model, unlike other APs, can be extended to fit required granularity or business domain. The 'holes' of the figure 2 can then be filled in with the appropriate data model specialization.

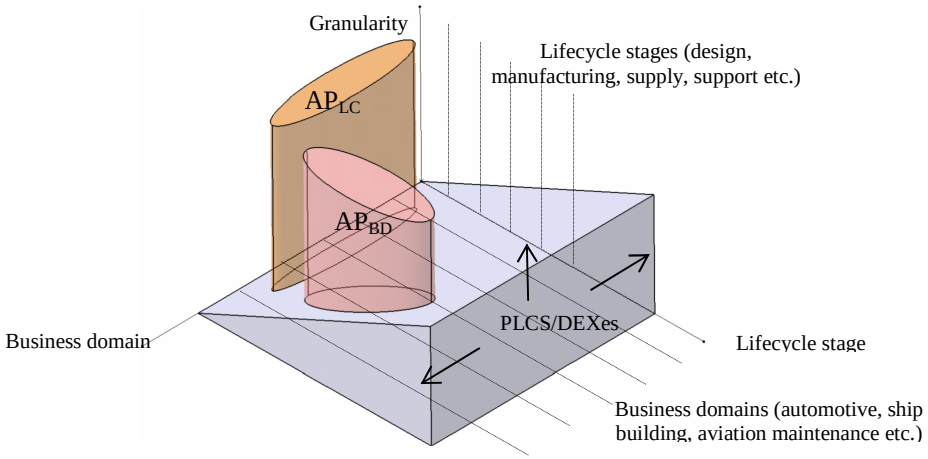

Figure 3 3D Map representation of STEP Application Protocols

5 Proposed framework for PDM/ERP interoperability

5.1 Functional architecture

This section presents the PDM/ERP interoperability framework (cf. fig.4) based on a service oriented mediator (*cf.* §3.3) and the PLCS product data model (*cf.* §4). To avoid the redundancy of data, a volatile mapping between ERP and PDM objects is performed. Data flow and workflows orchestration are driven by business needs, *i.e.* fit the end-user of one system to grab from or populate data to the other system. This framework is composed of (from bottom to top on the figure 4):

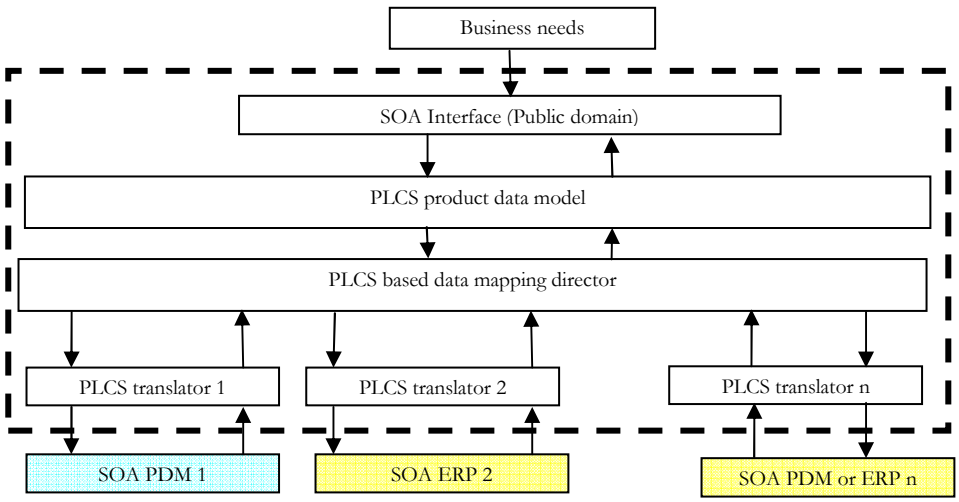

Figure 4 The PLCS/IT mediator based architecture

- a set of PLCS translators, that convert the PDM or ERP requested object to or from a PLCS object,
- a data mapping director, which merges the information from the translators in a coherent PLCS description,
- a complete PDM and ERP semantic representation using the PLCS specialized data model. This data model feeds the data mapping whenever needed,
- a public layer intended to receive user queries and return appropriate information. This layer is the SOA part of the framework.

5.2 Implementation decisions

A set of use-cases coming from industrial partners are about to be tested. These tests will involve PTC Windchill as well as the free ERP system OpenERP. The free and open source JSDAI API will be used to access the core AP239 data model, PLM services being implemented with the Zolera SOAP Infrastructure (ZSI) framework. The technical architecture is described in fig.5:

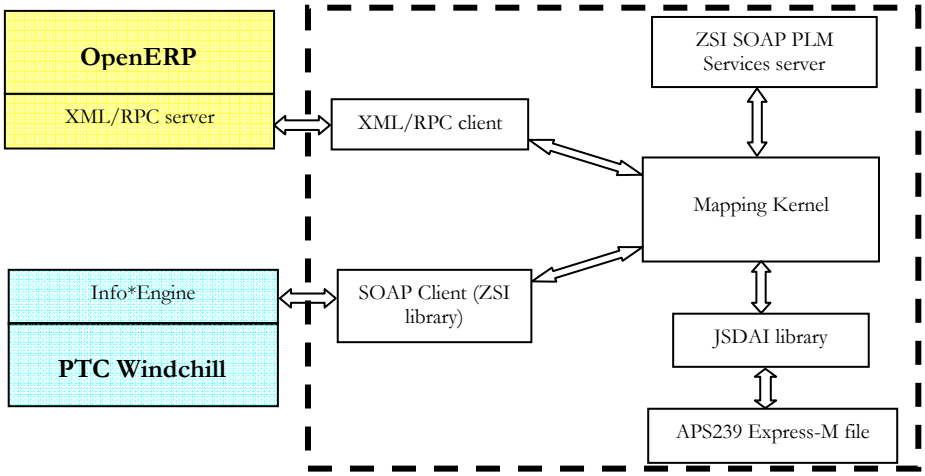

Figure 5 Technical architecture

6 Conclusion and further work

The PDM/ERP interoperability is still an issue for most industrial companies, especially those focused on long lifecycle products. However, an approach based on open standards can overcome these economical as well as technical issues. The use of the STEP PLCS standard can reconcile the design and logistics viewpoints under the condition that the generic data model is specialized according to this semantic extension. The PDMSchema, partly embedded in PLCS, is a natural bridge towards PDM but the ERP semantics, based on the concept of real product and processes, still requires an ontology description. The implementation part of this work will be achieved using the framework presented above, and lead to a demonstrator designed as a proof-of-concept for an industrial deployment.

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