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ENGESIS-PLM: A TRANSDISCIPLINARY PROCESS ORIENTED ENVIRONMENT TO SUPPORT THE DESIGN PHASE OF SYSTEMS ENGINEERING IN SPACE MISSIONS

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Abstract. *This paper describes the implementation of a software environment called ENGESIS-Product Lifecycle Management System to support the automated execution and management of the essential procedures of the systems concurrent engineering lifecycle processes, as an alternative to complete and/or tailored Product Lifecycle Management and Business Process Management systems. The environment consists in a set of integrated tools, put to work together in an interoperable way to support modelling, execution, analysis, and management of the product development life cycle processes, as an alternative to similar systems existing in the market, which are usually costly, complex, and difficult to customize and integrate with other enterprise´s legacy software applications.*

Keywords: Transdisciplinary Process Modeling. ENGESIS-Product Lifecycle Management Systems.

1. Introduction

The transdisciplinary process-oriented modeling approach here described, used for process model building and evolution, as well as for the conception of the architecture of its supporting environment, are based on a methodology denominated Transdisciplinary Process Science and Technology (T-PROST). The approach consists in the creation and implementation of specialized models, from a reference process meta model, of the integrated systems engineering and management processes, based on the techniques of Model Based Systems Engineering, Project Management, Business Process Management, and Systems Simulation.

The ENGESIS Framework [3] is a process modelling methodology that uses a transdisciplinary and innovative approach for modelling and analysis of the systems concurrent engineering lifecycle processes, making use of integrated techniques originated from different autonomous areas that deal with complex discrete event processes, namely: model based systems engineering, project management, business process management and simulation modelling.

Nowadays, there is a wide range of Product Lifecycle Management environments available to choose from in the market. Nevertheless, the majority of existing PLMS are

very complex, and they are costly and difficult to customize. Therefore, it is difficult to find friendly and affordable PLMS solutions in the market that can be customized for use by Transdisciplinary Small and Medium Enterprises (T-SME). These enterprises are characterized by their small size and project types comprehending up to 20 people and their business processes can be described with three levels of process breakdown, each one with at most ten activities, that is, comprehending a maximum of one thousand activities (10X10X10). This entails the possibility that project developments of this nature might be conducted in a very amateur way, leading to project failure regarding scope, duration, cost and/or poor quality of the products being built.

This paper presents the application of the ENGESIS Framework for the implementation of ENGESIS-PLMS environments, aiming at lowering the costs and improving the success rate of the so-called T-SME projects.

2. T-PROST´s Framework Architecture

The term Transdisciplinary Process Science and Technology (T-PROST) designates a holistic transdisciplinary and innovative view on discrete event processes that integrates and unifies concepts, methods and tools used in several autonomous disciplines that deal with solving problems involving discrete systems in general[1].

The architecture of the ENGESIS Framework (T-PROST´s Methodology with its complete supporting environment) presented in Figure 2.1 shows the integration and unification of concepts and tools originating from the disciplines of SE, PM, BPM and SIM. In this view, the tools that support the various disciplines are used individually, without any kind of integration. In this way, the models to be developed in each phase of the framework are created manually, separately, generating a high volume of work and possible inconsistencies between the various specialized models.

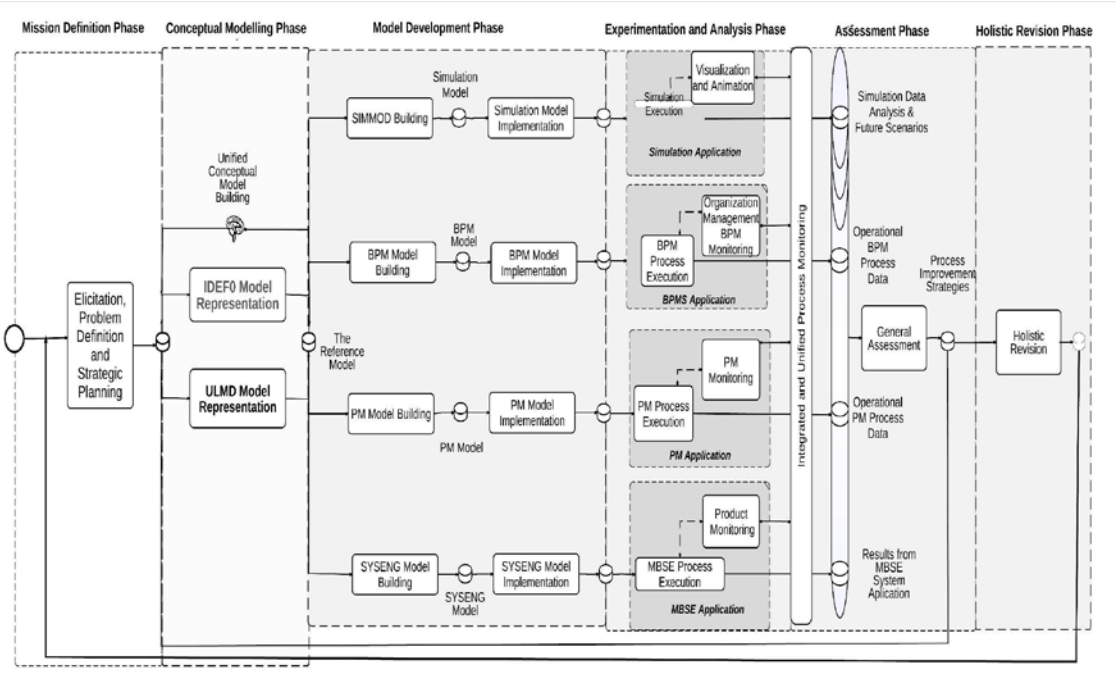

Figure 2.1 – The ENGESIS PLMS´ Architecture. Source [1].

The ENGESIS Framework, originally proposed in Kienbaum (2016), was used as the main base for the design and implementation of specializedPLM environments, such as the ENGESIS PLMS for use in the development of small satellites of type Cubesat, mentioned in this work.

3. Architecture of a Specialized ENGESIS PLMS Based on the ENGESIS Framework

The integrated use of applications from each of the individual areas of study mentioned in T-PROST and the joint analysis of their results can serve as the basis for the creation of a specialized type of PLMs, which can be termed in general , ENGESIS-PLMS.

A set of specialized models with their supporting applications is defined as a ENGESIS-PLMS if the software tools used have all the functionalities associated with the four T-PROST component disciplines to enable the management of the concurrent engineering lifecycle processes of systems according to their methodologies and techniques.

The general architecture of a ENGESIS-PLMS corresponds to the structured graphical representation of some elements, as shown in Figure 3.1.

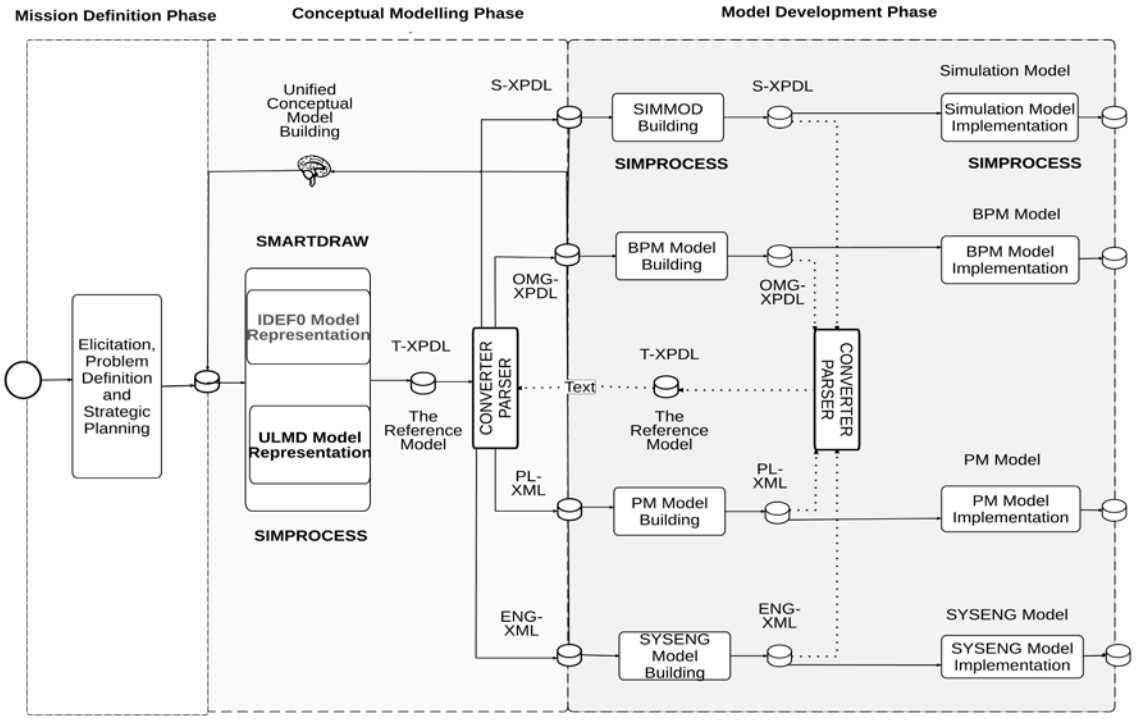

Figure 3.1 – The ENGESIS PLMS´ Architecture. Source [2].

The horizontal axis represents the evolution of process models throughout the life cycle. The vertical axis is used to display separately the layers representing the various disciplines, with their different techniques and support tools.

The rectangles correspond to the engineering processes, that is, to the transformations made for the evolution of the product throughout its life cycle. Rounded icons correspond to data repositories of some kind - complete models, objects, or artifacts of various natures - that are gradually transformed into other types of objects over the entire life cycle of specialized process models.

The processes are supported with the use of several specific tools, which are put together in the form of a set of interoperable components, to act as a specialized PLMS environment to support the application of the T-PROST framework in each study case.

4. The Architecture of ENGESIS-PLM Systems

A specialized ENGESIS-PLMS is composed by the integration of some Commercial-Off-The-Shelf (COTS) tools, used independently to deal with the disciplines of Project Management (GP), Business Process Management (GPN), Modeling and Systems Simulation(SIM).

The integration between the various tools is done by importing the files created by Jet-converter into their respective open formats, providing interoperability between the systems that make up the ENGESIS-PLMS environment. In this specialized environment, the converter was developed to meet only the first stage of transformation of the models, as suggested in the ENGESIS-PLMS´ architecture shown below. The reverse step, which transforms the revised models modified by the individual areas for input of these changes into the reference model, for common use by the other areas, was not implemented, as shown in figure 4.1 making use of dotted lines.

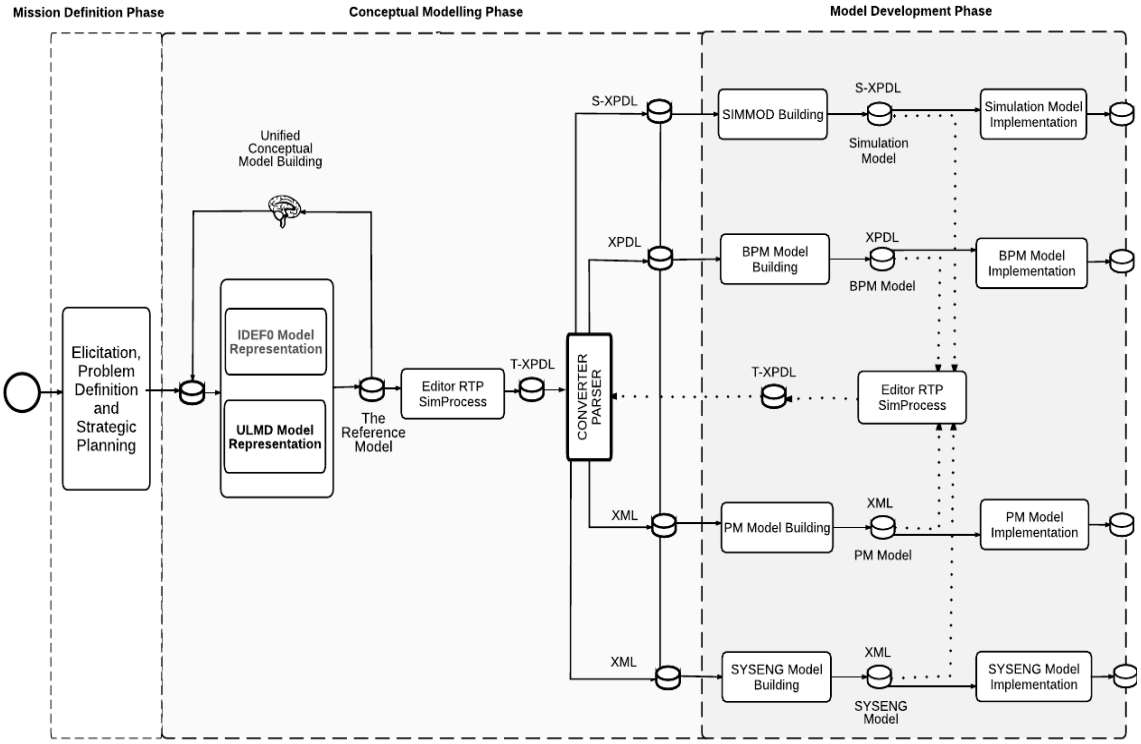

Figure 4.1 – The ENGESIS PLMS´ Architecture. Source [2].

The Jet-Converter application was developed to convert the T-XPDL files, created by RTP GUI Simprocess, into standard XPDL files and open XML and CVS standards, in order to overcome the deficiency in direct integration between individual tools.

The dotProject tool was used in the development of the environment by having its source code open, making it possible to add new modules, and to be executed in a

totally web environment. In order to perform the role of project management in an integrated way, within the ENGESIS-PLMS environment, an extension module for reading and exporting XML files was developed and added to dotProject by the author.

To support process management, which forms the core of a PLMS environment, the BIZAGI Studio suite was used. It is a tool that allows the full use of all its available functions, totally free of charge for up to 20 users, and it can be easily integrated with other systems. The implementation of the business process management model with some of its main characteristics was developed by the author.

The dotProject and BIZAGI Studio were used to provide the creation of a specialized PLM model using low cost or open source tools that are friendly for their users. The main element of the environment was the development of Jet-Converter, since once the reference model is exported in files with open formats of communication between systems such as (XML, CSV, XPDL), the tools can be replaced at any time , according to the needs and the constraints established by their application contexts.

5. The Design of an ENGESIS-PLMS for Use in Cubesats Development Lifecycle

The ENGESIS-PLMS for small satellites development consists in a set of integrated tools, put to work together in an interoperable way to support modelling, execution, analysis, and management of the their product development lifecycle processes. The demonstration of the potentialities of the methodology and its supporting environment is done by means of a pilot project, describing their application to the design phase processes in small satellites project development in space missions.

The final detailed structure of the ENGESIS-PLMS supporting environment, with its respective specialized component modules, is shown in Figure 5.1.

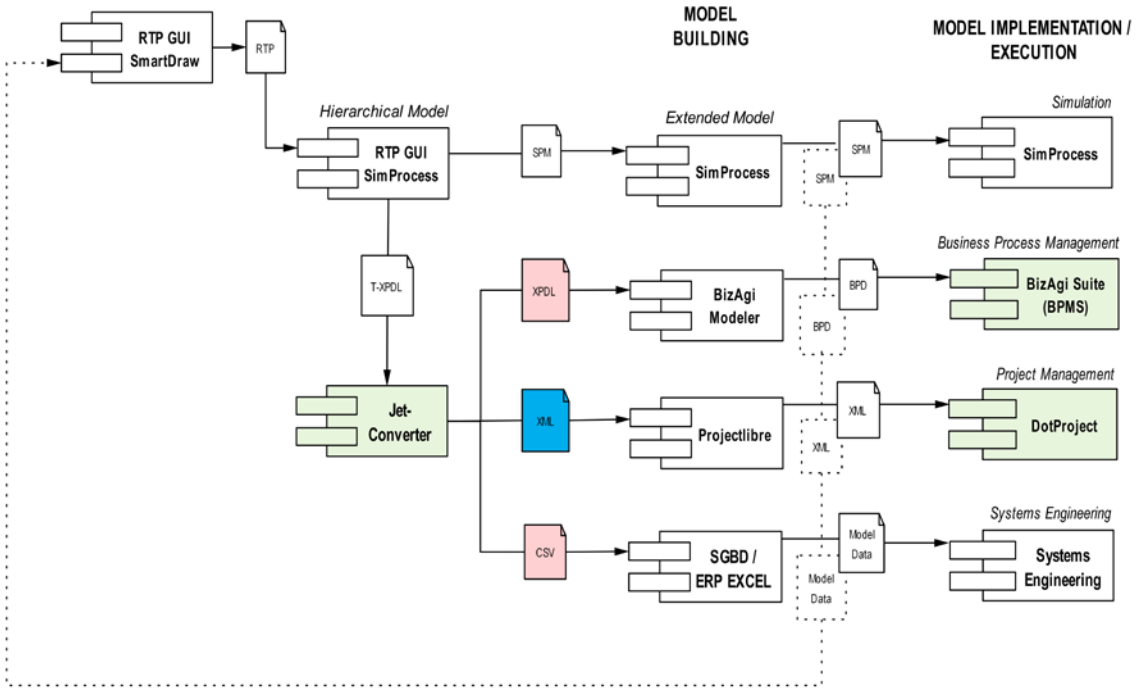

Figure 5.1 – The ENGESIS-PLMS environment.

The main features of the environment can be consolidated in the following functionalities: 1) Provide the conversion of the RTP process models into files with open communication formats (XPDL, CSV, XML), allowing them to be input into diverse tools with different characteristics, assuring the, integration and interoperability among these systems; 2) provide an interface for reading / exporting the RTP process model into XML format files, to be read by the dotProject system, allowing execution and management of the project based on the reference model information; and 3) Provide the execution, monitoring and control of the hierarchical process models created from the Transdisciplinary Process Networks (TPN) process model, making use of the BIZAGI Studio suite.

6. Discussion

The ENGESIS-PLMS (software environment) architecture is derived from the ENGESIS Framework (Methodology) architecture. The supporting tools originated from the disciplines of SE, PLM, PM e BPM are unified and integrated in the form of an environment, capable of supporting the modeling, the development, the execution, the automation, the monitoring and the analysis of the systems concurrent engineering lifecycle processes, aiming at continuous improvement.

The integrated use of the four types of model assessment techniques in T-PROST studies reveals that they have a complementary nature.

The complementarity of results is due to the fact that all specialized models make use of a reference model at the beginning of their model building process, which allows a joint and integrated evaluation of the product´s development lifecycle process model.

The combination of the four techniques is therefore very promising, but the use of existing software tools is subject to some limitations in terms of their interoperability, since they are designed for different purposes and do not take into account their complementary nature.

The proposed architecture for the creation of specialized ENGESIS PLMS is intended to address the above-identified deficiency, allowing the use of the various applications in a consistent manner, based both on the use of a transdisciplinary reference model of processes and on the automatic conversion between different types of PLMS. models.

In regard to the set of tools selected for the composition of the ENGESIS-PLMS environment here described (for use in the development of Cubesat satellites), the proposal was to make use of low-cost tools or academic licenses / open source and friendly to their users.

The implementation of the Jet-Converter application allowed the ENGESIS-PLMS environment to provide communication among the specialized tools, ensuring interoperability and making them work in a complementary way, providing automation mechanisms to help the use of the disciplines in a transdisciplinary way, in an integrated and simultaneous manner.

The tools used in the ENGESIS-PLMS environment can be replaced, where necessary, by other tools that work with open communication formats such as XML, CSV, XPDL, according to the needs and constraints established by the projects.

7. Conclusions

The ENGESIS framework presents a holistic view, consisting of the integration of several disciplines that deal with the modeling of complex discrete event process

problems: Model-Based Systems Engineering (ESBM), Project Management (PM), Business Process Management (BPM) and Simulation Modeling Systems (SIM), according to Kienbaum et al. (2016).

The implementation of a specialized ENGESIS-PLMS environment allowed the automation of some activities related to the implementation of the specialized models, which were previously executed manually and independently in the application of the ENGESIS framework.

In order to provide the integration and interoperability among systems, an application called Jet-Converter was created, whose main functionality is the conversion of TPN (T-XPDL) process models into files with open communication formats (XPDL, CSV, XML), followed by the import of the models into COTS type components and subsequent adjustments.

The Jet-Converter module, part of the ENGESIS-PLMS environment, was developed to meet only the first stage of conversion of the models, as suggested in the T-PROST methodology. This is done unidirectionally, transforming the reference model described in T-XPDL to the various standards mentioned above. This avoids the manual creation of specialized models in each of their respective tools.

8. References

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