Experimentation of an Enterprise Architecture in aerospace electrical engineering process

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Abstract. This paper deals with an experimentation of Enterprise Architecture practices applied to a case study spacecraft electrical engineering domain. Viewpoints conforming to IEEE Std 1471 definition were built from popular architecture framework such as Zachman. Particular issue in the field of enterprise engineering was reviewed such as: metamodel for vertical integration, normative corpus for reasoning and modelisation language choice. A reference structure is presented as a starting point for metamodel creation. We have conducted an implementation with System Architect tool. According a waterfall approach, the user scenario maps step by step software components and functionalities into disciplines business needs and business strategy. IT and business users have provided early feedbacks for an operational use in engineering scope.

Keywords. Enterprise Architecture, Enterprise Modeling, Electrical Engineering Process.

1 Electrical Business problematic

EADS space transportation is one of the major actors in aerospace industry. The multinational unit develops products and capabilities in orbital systems, launcher, ballistic missiles, system design integration, propulsion and equipment. The total sales result in 2004 was 2.6 billions for 11.000 employees[1].

The electrical department is in charge of design and development of embedded electrical systems and ground electrical systems. This study focuses on the development of electrical cables and connectors components as part of the final launcher.

The electrical product development involves many actors from the design phase to manufacturing and integration phase. Theses phases make use of intensive collaboration between disciplines in concurrent engineering processes; in our context these processes are distributed on several locations.

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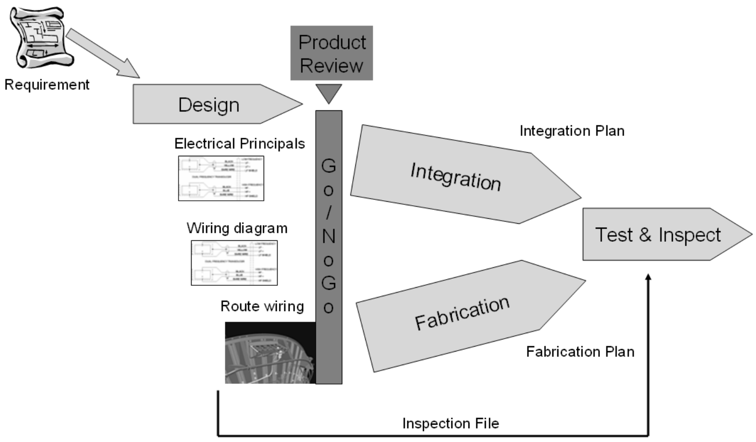

Figure 1. Electrical Business Process overview

The complete product development requirement is specified by the program management. At this level, product interfaces and functional requirements stage evolve with contractual acceptance of the client. The electrical department is in charge of enriching the technical solution with electrical business dossier for integration, fabrication and validation. A program commission states on design solution by evaluating technological risk, time and budget.

The problematic we address is an harmonization effort between multinational entities. The harmonization targets enterprise methods and tools such as CAD, exchange repository, data format, wiring diagram layout edition. Effort aims at a better integration of distributed business location by achieving common understanding of data, process and IT technology. The challenge is to plan roadmap to reach a common target from the actual background and legacy systems (As-is) to a future platform (to-be). The project involves multi stakeholder from business manager to IT engineer. Each concern should be represented and communicated efficiently to produce insightful vision. The problem to be solved is to identify technical and business criteria to identify high added value processes and information systems.

2 Enterprise Architecture

Current economic competitivity forces enterprise to lean their manufacturing and mangement operations to be more productive and efficient. Technological information potentially extends business capabilities by enabling collaborative practices on virtual product [2] and by enabling share space through Product Data Management solution [3]. Enterprise Architecture is a discipline that considers the enterprise as a system.

Architecture intends to capture components of a system, their organizations, and the relation to the environment. This definition is provided in the IEEE Std

1471-2000 [4] which gives a frame of reference and set of definitions targetting architectural description.

The standard defines the entity *model*. In our case model encompasses ER (entity relation) grammar such as UML Class Diagram [5,21], Process grammar like BPMN (Business Process Modeling Notation) [6], but also DfD (Data Flow Diagram) grammar such as Gane & Sarson diagram [7].

Stakeholder and associated *concerns* [8] are expressed into *viewpoints*. A *view* may consist of one or more *models* conforming to *viewpoint*. The standard does not provided recommendation for *viewpoints* choice [9]. External reference viewpoints are provided by many frameworks [10]. We review for the purpose of the study many architectures: Zachman Framework Architecture [11], Department of Defence Architecture System View [12], 4+1 views [13], TOGAF [14]. We focused on Zachman as a framework to think and organize viewpoints and DoD AF for ready to use system definition view.

3 Architecture exploitation mode

Information about relation and properties of elements to be managed is given by actors and available procedures documentations. Experience and know how can be extracted from different interviews. Elicitation method depends on the task [15]. Formalization range is defined in early phase of the architecture life cycle in accordance with stakeholder interest and needs.

Interest and concerns participate to build exploitation mode. Most interests are leaded by harmonization effort to build common policy in product management and to identify common IT building blocks that enables process and method. Business units' integration requires exchange capabilities at technological level and process level.

The architecture was designed to deliver model for communication and for supporting balanced decision. Elements associated to domain criteria such as time and cost provide key driver for discussion. The architecture aims at providing indicators to build and implement a target (to be) IT and process reference, and identify path from the (as is) architecture.

From the electrical perspective, the raised questions were which electrical process should be optimized, and what is the best support to communicate efficiently from business point of view to IT engineer. Further identified functions were to manage evaluation of method and tool change impact. Scenario provides a frame to elicit user query and possible solution that the architecture could provide in decision process.

4 Building electrical viewpoint

An informed decision is taken by balancing multiple criteria. In order to tackle different goals and concerns in the architecture, we designed a set of viewpoints to collect independent but interconnected models. From business to IT capabilities we defined: Business Context, Business Functional, Discipline Capabilities, Application Architecture and Infrastructure.

Viewpoint definition conforms to IEEE 1471. The viewpoint is structured by properties such as the name, eligible stakeholder, stakeholder concern addressed by the viewpoint, language and modeling techniques, the source of the viewpoint. In our case viewpoints inherits from Zachman's cells [16] and DoD AF system view [17]. Viewpoint is further described with analysis and evaluation method to be applied within the view, with any formal or informal completeness checks associated to the underlying method, and with any patterns or guidelines for model creation and reviewing.

Two viewpoints are represented here: discipline capabilities and IS architecture.

Table 1. Business and IT viewpoint definition

Name	Discipline Capabilities	Applications architecture
Eligible stakeholder	Electrical engineer in the design, production and integration field	IT analyst and engineer
List of concerns	How the people are working (business process) to fulfill enterprise function? Which are the associated applications ? What are the processed data? Who are involved in the business process? Where are entities involved in exchanged?	Which technologies are used? How applications are divided into module? What is the interface between applications? How exchanges are constrained? Applications support which operations?
Modelling techniques and associated definitions	BPMN (process, message flow , event, sequence flow, pool, lane) Entity Relation (element, relation), Organization chart (organizations units, decomposition relation, role) and matrix edition (elementary business process to data element, to application, to role, to technology)	Data Flow diagram from Gane&Sarson (Process, Data Flow, Physical Flow, Data Store, External), UML Class Diagram (Class, relation), Custom diagram from Gane&Sarson named System Architecture Map (Application, data flow)
Viewpoint's source	Zachman Business model	DoD AF system view SV1, SV4, SV5
Evaluation method	Conformance of business process to electrical operations, design and assess to-be process	Overview of applications deployment and exchange. Understand the current state and prepare a to-be architecture
Completeness checks	Elicit experiment rules to assess viewpoint consistency e.g.; consistency description of elementary business model with associated applications, technology, roles, data element. Theses checklists could specify synchronization of element from different grammar and reference to scenario description.	
Guidelines	Internal resources that describe and improve modelling comprehension	

Structured guideline advices good practises in model exploitation and model creation. It provides to learner but also to confirmed practitioner method to verify completeness and correctness in designing and reviewing architecture elements (i.e.: naming rules, existing equivalent element to be reused).

Viewpoint prescribes definition and modeling techniques. Small artifact, term and grammar enable to cut the complexity into a set of clusters [18]. More precise viewpoint can be added. Construction of architectural viewpoint allows people promoting specific concerns [19,20]. It offers opportunity to foster exchange between communities such as business manager, IT engineer, discipline actor [22].

Two views were implemented according previous viewpoint. Some extracted models are inserted below.

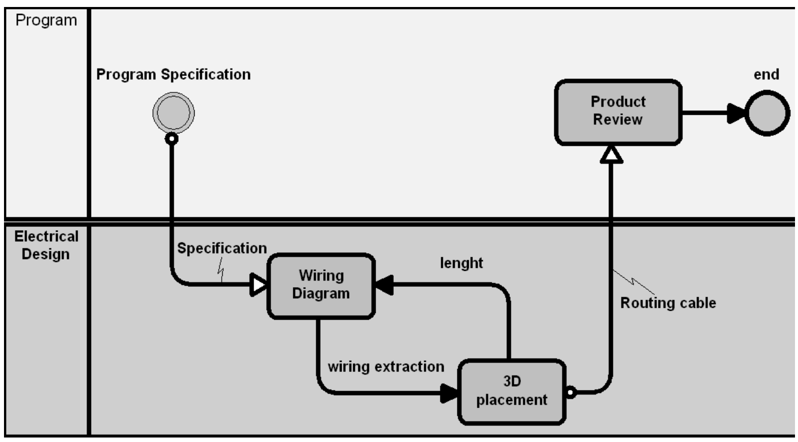

Figure 2. Electrical design Process in BPMN

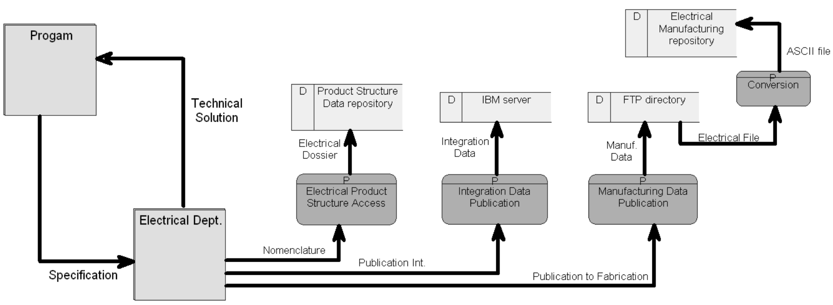

Figure 3. Electrical Design repository access (custom representation in Gane & Sarson like)

The first diagram is a big picture of electrical design process. The second diagram shows data repository accessed by electrical department after “program commission” approval of the design solution.

Electrical business process provides a description in BPMN. Association between process and actor is provided by horizontal pool in BPMN diagram. In addition to the graphical description, templates describe each element of the grammar with attributes, link to other elements and textual description. The description provides input for simulation and analysis purpose.

5 Reference construct and metamodel for interogation

Function of the information model is supported by element properties [23]. Graphical symbols and diagram depict a point of view by using dialects compliant with a grammar. The choice of a grammar is balanced between expressivity and complexity [24]. In order to allow problem solving across several viewpoint elements, an integration is required at different level. For that purpose we developed a construct reference for metamodel creation.

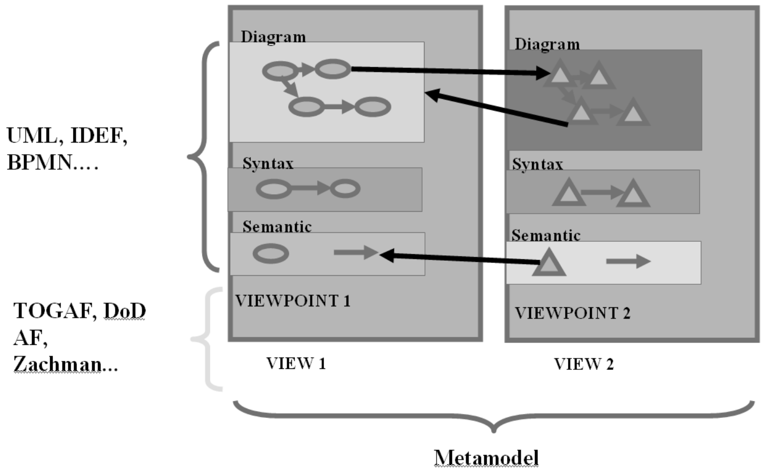

Figure 4. Reference construct for metamodel creation

Element is an artefact of the real world. It portrays enterprise asset [25]. Combination and cross usage of element extend the semantic coverage for problem solving.

Basic elements participate to diagram description, and are depicted according to a syntax. In addition to that, different types of links enhance element description. The first one is that two elements are synonym but expressed in different grammar. As an example, a lane in BPMN is equivalent to an organizational unit in organization chart. Second kind of link expresses a role relation between elements. Theses links are generally saved by inter domain matrix.

Matrix dependencies accurate navigation and reasoning from elements links and properties. Linking different view help to understand about what is really happening in an enterprise process.

The corpus manipulated from the architecture was restricted to six concepts: Process (P), Discipline Object (O), IS application (A), Function (F), people organizations (P&O), Requirement (R). All are used in viewpoint in a particular grammar. Metamodel was constructed by using the reference constructs in order to join concepts by retrieving link between diagram elements.

As an example, FxPxO contributes to discover and extract views and diagrams that define, for a particular function, which process contributes to that function and what is the discipline data involved.

In general manner, user query and performance analysis is a balancing process to find optimum for P x O x A x F x P&0 x R.

In addition to the concept declaration we add two time scales in the architecture. The first expressed the starting point of the business capabilities and is called as-is. The second time scale expressed a target architecture that provides clues for future deployment hypothesis.

6 Experimentation result

The electrical architecture was implemented in System Architect Tool from Telelogic. The 10.1 version of the tool comes with high customization capabilities and functions to increase grammar and entity relation. A Visual basic module enables to query the database and check constraint. In standard version many grammars are available. The high expressivity of the tool requires a well defined methodology in order limit scope of exploitation.

Despite the fact that the demonstrator was not used at the operational level, the electrical repository was tested with a subset of stakeholders from business and IT departments. Several viewpoints were implemented, but the architecture was not used in configured multi-user project mode. We can draw general conclusion from the project.

In general, modelisation happens at a high level and deals with enterprise process. The intention is to capture key performance indicator and to provide guidance for process compliancy with business scorecard. Further detail model in order to describe how to do a process is not covered.

Our architecture intention was to describe an electrical operational level. This operational level describes the “How to do” more than “What to do”. Process, but also know-how and business data are in the scope of the architecture. At this level, a huge amount of information is processed by actor in day to day tasks. Process is more flexible and working hypothesis move rapidly during exchange and collaborative engineering work. Consolidated criteria for process evaluation depend on real data and uncountable number of situations.

In our case interviews’ provide actor knowledge about activity. It is a good input to create diagram, identified concept and built scenario. Numerous aspects of engineering activities imply numerous artifact and grammar. Exploitation and creation of diagram do not belong to the operational actors’ domain of competencies. We had to organize learning events to help users and to fill the gap. We noticed that the more user’ interests is taking into account, the more learning time is required.

Displays and views extractions play an important part for user adoption. The development of view extraction required customization out of the project scope.

As for the methodology used in TOVE [26] for ontology creation, we put effort in queries and user scenarios to handle complexity. Ideally, each object and each property should be a consequence of a user oriented scenario. As a result, in order to demonstrate how the user can have confidence in the model, our testing purposes were based on scenario. We believed that efforts in interface development can not be avoided for exploitation. The current exploitation was to developed architecture as a communication support but also as a knowledge base for insightful information extraction.

The most promising use at operational level, that encompasses both communication purpose and knowledge retrieval, deals with formalization of user guide and best practices in engineering tool such as CAD and PDM applications. In our opinion, architecture repository contains enough information and semantic data to structure a methodological web site for electrical engineering activities.

Concerning the tool, we acknowledge that implementations are not restricted by System Architect tool, but should be constrained by a methodology in order to provide means for a consistent repository. On the contrary, tool restricted by grammar or method does not allow a full expressivity required to formalize product engineering activities.

7 Conclusion

The analysis performed in this paper shows that enterprise architecture can be used to represent an overall picture of a business electrical process more than to provide performance indicator on business process. Complexity of knowledge representation was subdivided into manageable viewpoint. And viewpoint artefacts are linked through a metamodel based on a reference construct including element description, element depictions and cross domain reference.

In addition to methodological repository, enterprise paradigms can assist product decision making process. Terminology is one of the major challenges in the field of integrated architecture engineering. The ontology development approach used in this paper is more top down oriented. User requirement and scenario are the basis to deepen concept identification and syntactic definition. Modelling competencies acquisition is a prerequisite at an engineering user point of view to foster the deployment of operational architecture.

8 Reference

[1] EADS Space, Communications and Public relations Directorate. EADS Space leaflet. www.space-eads.net.

[2] Mager R, Hartmann R. The Satellite design office at Astrium – A Success Story of an Induistrial Design Center Application. Proceedings of EuSEC 2000.

[3] Kesseler E, Kos J. The next step in collaborative aerospace engineering. 3rd International conference RIVF'05 2005.

[4] IEEE. Recommended Practise for Architectural Description of Software-Intensive Systems-Description. IEEE Std 1471-2000

[5] OMG- Object Management Group Inc. Unified Modeling Language Specification, version 1.3. http://www.omg.org
[6] Business Process Management Initiative.BPMI.org.Business Process Modeling Notation.(BPMN) version 1.0, May 2004
[7] McClure C. The CASE for structured development. PC TECH J. 1988; 6: 50-69.
[8] Koning H, Bos R, Brinkkemper S. An inquiry Tool for Stakeholder Concerns of Architectural Viewpoints : a Case Study at a Large Financial Service Provider. EDOCW'O6 2006. p.31
[9] Hilliard R. IEEE Std 1471 and Beyond. SEI's first Architecture Representation wokshop January 2001.
[10] Fox MS, Gruninger M. Enterprise Modeling. American Association for Artificial Intelligence1998: 109-121.
[11] Sowa JF, Zachman JA. Extending and formalizing the framework for information information system architecture. IBM Systems Journal 1992;31:590-616
[12] C4ISR Architecture Working Group, US Department of Defense. C4ISR Architecture Framework Version 2.0
[13] Kruchten P. Architectural Blueprints – The "4+1" View Model of Software Architecture. IEEE Software 1995; 12:42-50
[14] TOGAF: The Open Group Architecture Framework "Enterprise Edition" version 8.1. Available at: http://www.opengroup.org/architecture/togaf8-doc/arch>. Accessed on: Feb. 5th 2007.
[15] Maiden NAM, Rugg G. ACRE: a framework for acquisition of requirements. Software Engineering Journal, 1996; 11:183-192
[16] Zachman JA. Entreprise Architecture – a framework. ZIFA, Zachman Internationnal. Available at:< www.zifa.com>. Accessed on : Janu. 17th 2005
[17] Noran O. A systematic evaluation of the C4ISR AF using ISO15704 annex A(GERAM). Computer in Industry 2005; 5:407-427
[18] Ducq Y, Chen David, Vallespir B. Interoperability in enterprise modelling : requirement and roadmap. Advanced Engineering Informatics 2004;18:193-203
[19] Wegmann A, Balabko P, Lê LS, Regev G, Rychkova I. A method and Tool for Business-IT alignement in Enterprise Architecture, The 17th Conference on advanced Information Systems Engineering 2005:161
[20] Toussaint P. Bakker AR, Groenewegen LPJ. Constructing an Enteprise Viewpoint: evaluation of four business modelling techniques. Computer Methods and Programs in BioMedecine 1998; 55:11-30
[21] Hilard R. Using the UML for Architectural Description. Proccedings of "UML 1999; 1723
[22] Kosanke K, Nell JG. Standardisation in ISO for enterprse engineering and integration. Computer in Industry 1999;40:311-319
[23] Mertins K, Jochem R. Architectures, methods and tools for enterprise engineering. Int J Productions Economics 2005;98:179-188
[24] GERAM GERAM: Generalised Enterprise Reference Architecture and Methodology IFIP–IFAC Task Force on Architectures for Enterprise Integration, version 1.6.3 1999.
[25] Bernus P. Enterprise models for enterprise architecture and ISO9000:2000. Annual Reviews in Control 2003; 27:211-220
[26] TOVE. Toronto Virtual Enterprise. Available at: <http://www.eil.toronto.ca/tove/ontoTOC.html>. Accessed on: Feb. 6th 2007.