Positioning the System Architecture Process

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1 Introduction

This article will be succeeded by a more modular set of articles, preliminiary decomposition:

- What is a Process (Intermezzo)
- Process Decomposition of a Business
- The Product Creation Process[5]
- The Policy and Planning Process
- The System Architecture Process

System architecture is being recognized as a critical process in developing complex products, while system architecture skills are scarce.

Currently system architecting is much of an art, and no clear definition exists for system architecture, while the process of creating, maintaining and evolving a system architecture is also in its early infancy.

This article positions the system architecture process in a wider business scope. This positioning is intended to help understanding the process itself and the role of the system architect (or team of system architects). Unless explicitly stated otherwise the term system architect in this article can be read as team of system architects as well.

It focuses on system architecture within an organization which creates and builds systems consisting of hardware and software. Although other product areas such as solution providers, services, courseware etcetera also need system architects, the process structure will deviate from the structure as presented here.

This article is primarily written for system architects, potential system architects and people which determine the context in which the system architect operates. The article starts with a high level overview of the context in which system architecture is applied, zooms in to the mainactivities in the system architecture process. The article finishes with another abstraction to show the system architecture process in a map of system architecture related processes.

Section 2 is a preamble defining "process" for the context of this article, since this word is heavily overloaded. Section 3 up to 6 discusses the positioning itself.

An excellent book about system architecture is [7]. The book [4] shows a more mature process for System Engineering. This article will fit into a series of articles produced by the Gaudí project as described and partially published in [6].

2 What is a process

To begin the discussion of positioning the system architecture process, a definition or better understanding of the notion "process" is required. In this article a process is seen as an abstracted way of working. A process can be characterized by the following attributes:

Purpose What is to be achieved and why

Structure How will the goal be achieved

Rationale What is the reasoning behind this process

Roles Which roles are present, which responsibilities are associated, which incentives are present, what are the criteria for these roles

Ordering Which phasing or sequence is applied

In [3] the following definition is given:

A process is an activity which takes place over time and which has a precise aim regarding the result to be achieved. The concept of a process is hierarchical which means that a process may consist of a partially ordered set of subprocesses.

This definition parallels the characterization above. It adds explicitly the potential hierarchical decomposition of the process itself. In this article the emphasis will be more on the relations between several processes than on the hierarchy of the processes themselves.

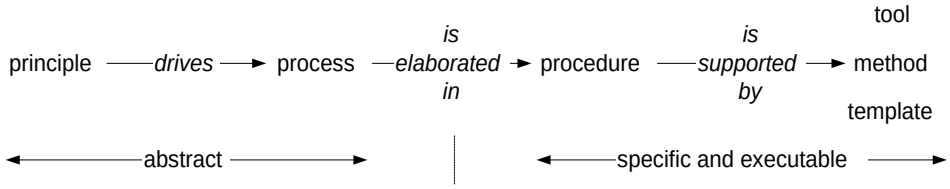

Figure 1: A process within an abstraction hierarchy

The notion of a process can be seen as one step in an abstraction hierarchy, as shown in 1. The most abstract notion in this hierarchy is the "principle". In the context of the Gaudí project it is planned to explain this notion further in an additional article, see also [6].

A process is rather abstract. It describes the essentials of the purpose, structure, rationale, roles and timing, leaving plenty of implementation freedom. The power of a process is its abstraction, which enables its application in a wide range of applications, by tailoring its implementation to the specific application.

A process can be tailored and elaborated in one or more procedures, which describe cookbook-like what need to be done when and by whom. The why in a procedure has often disappeared. The implementation of a procedure is supported by tools, methods, templates and other means.

Many processes are required to ensure the effective functioning of an organization. These processes are interrelated and overlapping. Processes are non-orthogonal and don't fit in a strict hierarchical structure.

Most complex product developments don't fit in the classical hierarchical organization model, but require a much more dynamic organization model, such as the currently popular chaos based network organization. Processes are the means which help to ensure the output of dynamic organization models such as a chaos based network organization.

Processes can be seen as the blueprint for the behaviour of the people within the organization. People will fullfill multiple roles in multiple processes. The process

description is intended to give them an hold on what is expected from them.

The 80/20 rule is also valid for processes: 80% of the behaviour is covered by the processes, while 20% requires independent creative behaviour. An organization without processes drowns in chaos, while an organization which blindly implements them will be killed by its own inertia, its inability to adapt to the fast changing world.

3 Process Decomposition

The business process for an organization which creates and builds systems consisting of hardware and software is decomposed in 4 main processes as shown in figure 2.

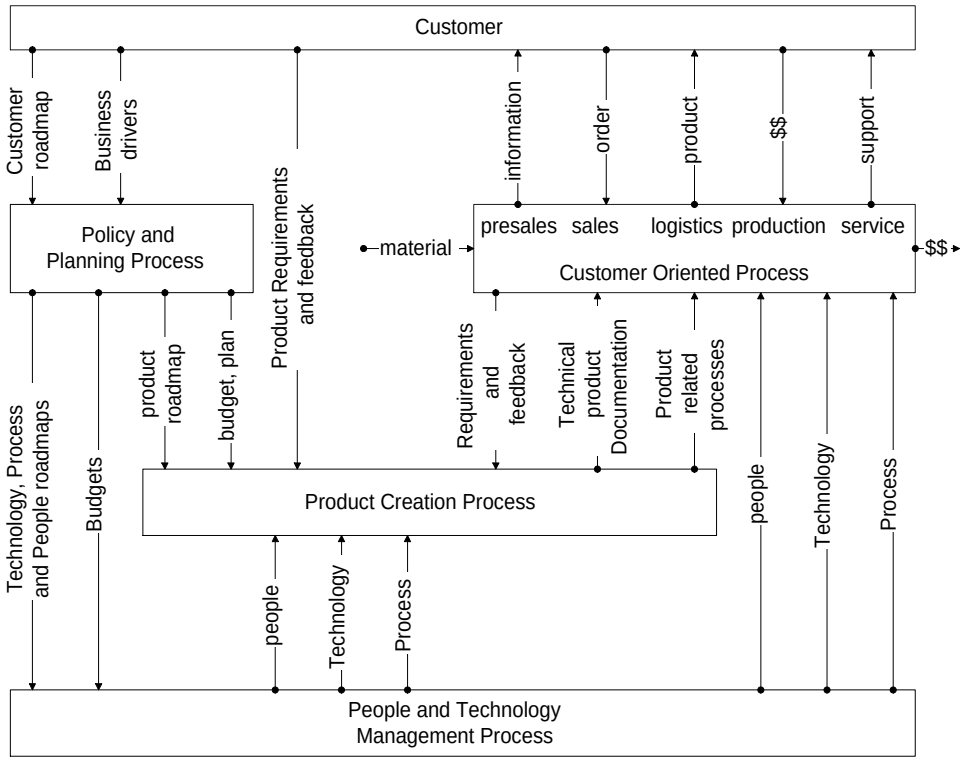

Figure 2: Simplified decomposition of the business in 4 main processes

The decomposition in 4 main processes leaves out all connecting supporting and other processes. The function of the 4 main processes is:

Customer Oriented Process This process performs in repetitive mode all direct interaction with the customer. This primary process is the cashflow generating part of the enterprise. All other processes only spend money.

Product Creation Process This Process feeds the Customer Oriented Process with new products. This process ensures the continuity of the enterprise by creating products which enables the primary process to generate cashflow tommorow as well.

People and Technology Management Process Here the main assets of the company are managed: the know how and skills residing in people.

Policy and Planning Process This process is future oriented, not constrained by short term goals, it is defining the future direction of the company by means of roadmaps. These roadmaps give direction to the Product Creation Process and the People and Technology Management Process. For the medium term these roadmaps are transformed in budgets and plans, which are commital for all stakeholders.

This process decomposition is not an organization. A single person can (and often will) fullfill several roles in different processes. The system architect specifically will spend most of his time in the product creation (ca. 75%), a considerable amount of time in the policy and planning process (ca 20%) and a small fraction of his time in the people and technology management.

The 4 processes as described here are different in nature. The Customer oriented process executes over and over a well defined set of activities. The system architect does not participate in active role in this process. However since the Customer Oriented Process is the main customer of the Product Creation Process, it is imminent that the system architect understands, or better has experienced, the Customer Oriented Process.

In different scopes than the limited scope of organizations which create and builds systems consisting of hardware and software, for instance in solution oriented businesses, the architecture function can be even closer to the customer. This function can be fullfilled by the system architect or by more specialized architects, for instance a solution architect.

The system architect is in continuous interaction with many people, mostly about technical aspects. From this perspective he will generate inputs for the People and Technology Management Process. This might even result in participation in this process for instance by coaching, participation in the appraisal process or participation in technology studies.

The number of instances of each process is related to different entities:

Customer Oriented Process depends on geography, customer base and supply chain.

Product Creation Process one per entity to be developed, where such an entity can be a product family, a product or a subsystem.

People and Technology Management Process one per "competence", where a competence is a cohesive set of technologies and methods.

Policy and Planning Process one per business, this is the pro-active integrating process.

The split up of the Policy and Planning Process from the Product Creation Process gives the Product Creation Process a clear focus: the entity to be developed.

In this decomposition the evolutionary development of product variants and new releases are seen as individual instances of the Product Creation Process. For example the development of a single new feature for an existing product is performed by following the entire Product Creation Process. Of course some steps in the process will be (nearly) empty, which does not cause any harm.

4 Product Creation Process

The Product Creation Process is the process which transforms an idea or concept into a sellable, manufacturable and serviceable product. Such an activity is by definition a joined effort of all business disciplines, ranging from marketing and development engineers to manufacturing and service engineers. However the core of the process is creative and technical.

4.1 Further Decomposition

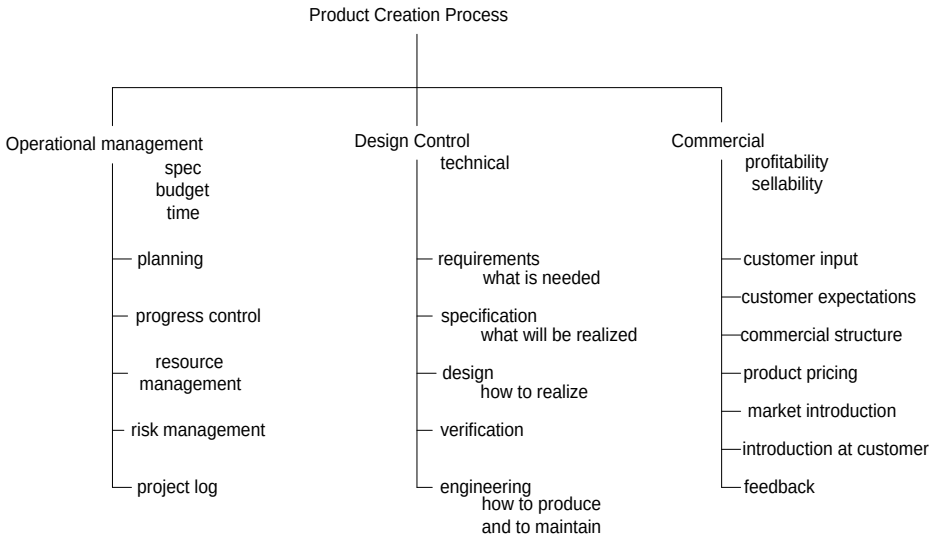

Figure 3: Product Creation Process decomposition

The Product Creation Process is decomposed in 3 strongly coupled processes, as shown in figure 3:

Commercial defining how to obtain a sellable profitable product, starting with listening to customers, followed by managing the customer expectations, introducing the product at the customer and obtaining customer feedback.

Project Management realizing the product in the agreed triangle of

- specification
- amount of time
- resources

Design Control Specifying and designing the system; This is the home base of the system architecture process.

The ISO 9000 standard has a number of requirements with respect to the "design control" process. The design control process is a hardcore technical process, as stated above it is the home base of the system architect. The system architect will support the project management and the commercial process.

The design control process itself is further decomposed, also shown in figure 3:

- Requirements
- Specification
- Design
- Engineering
- Verification

The word requirements is quite heavily overloaded. In this context requirements is used to express what the application or user requires of the product, not yet constrained by business or technical considerations. Most development engineers tend to forget the original requirement after several iterations of commercial and technical trade-offs.

The specification describes what will be realized, in terms of functionality and performance. This specification is the agreement with all stakeholders. The difference between the requirements and the specification is that in the specification all trade-offs have been made.

The design is the description how the specification will be realized. For instance the physical and functional decomposition, the budgets for critical technical resources etcetera belong to the design.

Requirements, specification and design are documented in development documents. The main function of these documents is to streamline the Product Creation Process. During this process these are living documents fullfilling an important communication function, while at the same time they play an important role in the control aspect of the design process.

The verification proces verifies that the implementation meets the specification in the way it is specified in the design.

The engineering process provides the basis upon which the customer oriented process works for the entire lifecycle of the product. The documentation generated in the engineering process is the output of the Product Creation Process.

4.2 Phases

Most companies today work with phased approach in the Product Creation Process. A phase model is a means to structure the product creation process. The phase model serves as a generic blueprint for product developments. It is an evolving model, showing the crucial deliverables with the **Who**, **When** and **What**. Figure 4 shows the typical phases in such a model. Most models have between 4 and 7 main phases defined.

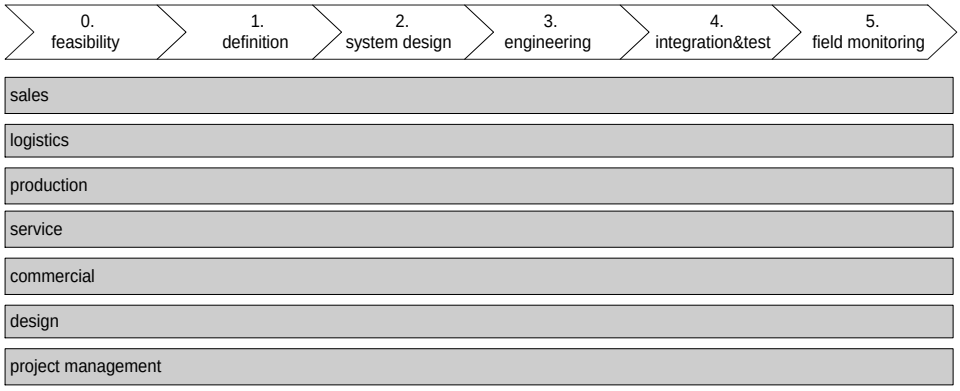

Figure 4: PCP phases applicable to all business functions

These phases are used across all business functions which have to participate in the Product Creation Process. It is a means to manage the relations between these functions and to synchronize them. Note that sales, production, logistics and service people are involved in the Product Creation Process. Their participation is required to understand the input from the customer oriented process and to help developing the new processes for the customer oriented process.

The phase model serves multiple purposes:

- it helps project members in structuring the project, not everything need to be invented from scratch

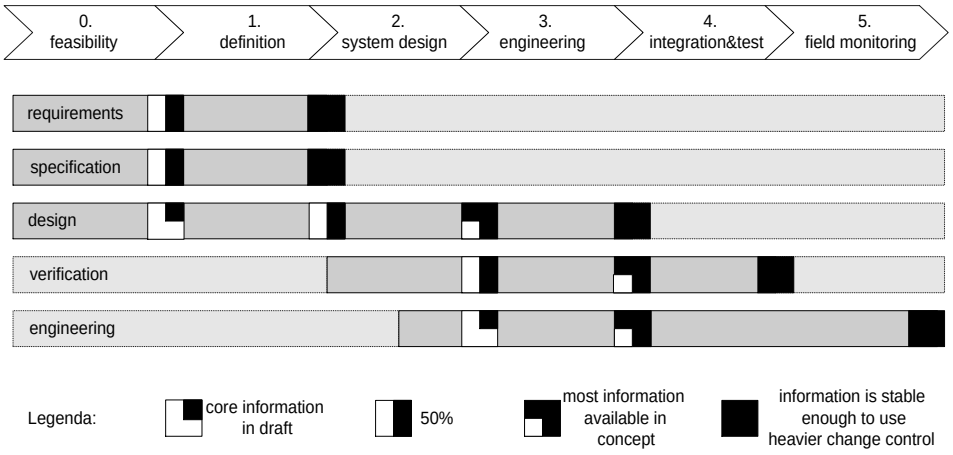

Figure 5: Design activities during the PCP phases

- it serves as a shared framework for all project members and stakeholders
- it consolidates product creation experience
- the management team has a reference to judge the status of the project

The activities in the design control process are also shown in figure 5. This shows a number of important characteristics of a phase model:

Concurrency of most activities enabling iteration, and

Checkpoints halfway or more frequent

The phase model stresses and supports concurrent activities, see also [2]. A common pitfall is a waterfall interpretation of a phased approach. This can be very costly mistake, because feedback from implementation and customers is in that case too late in the process. Early and continuous feedback both from implementation as from customer point of view is essential.

The system architect will be present for more than 50% of his time in the first 5 phases, while fading out during the field monitoring phase. In the early phases, when the team is still small, he plays a very prominent role. The role in the middle phases is most often severely underestimated. In these phases the system architect maintains the consistency, integrity and balance of specification and design.

5 Policy and Planning Process

The policy and planning process generates a non-commital outlook, called roadmap, covering:

market what does the outside world require or expect

products which product portfolio will be made in response to the market

technology which technology is required to develop this product portfolio

process which processes are required to develop the products with the identified technolgy

people which people and skills are needed to implement the above.

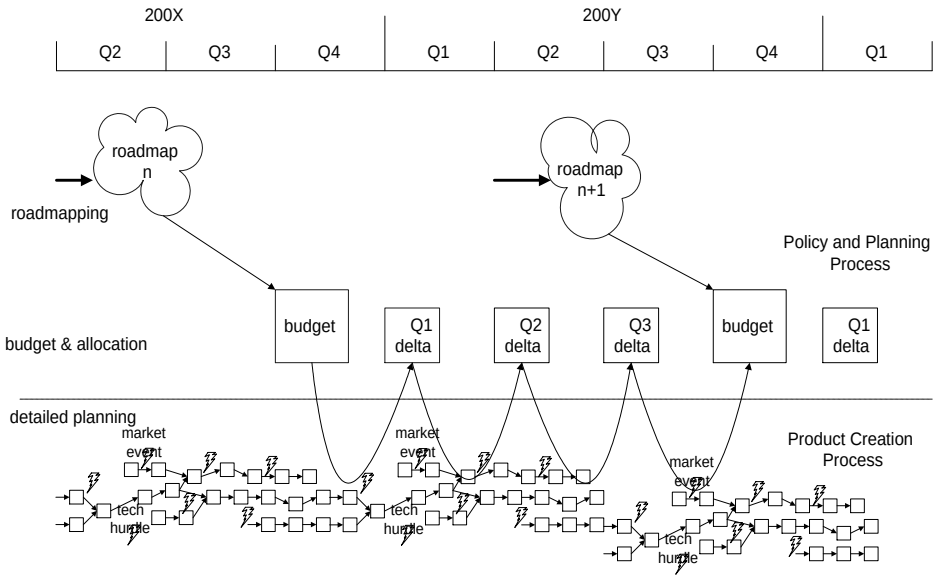

Figure 6: From long term roadmap, via medium term budget to short term detailed plan

It is essential that this entire roadmap is consistent, which will cost a few iterations to match the needs of the markets with the capabilities of the organization. The emphasis of these iterations should be in the "requirement" direction:

The market requires products, which in turn require technology, which require processes and people to be used.

The roadmap serves as a context for the definition of the medium term budgets and plans. These budgets and plans are committal. Changing them will have consequences for the involved stakeholders.

The budget as mentioned here is the combined set of project definitions. Every project definition defines per project the output, the specific resources and the timing of output and resources [1].

[1]The commitment described earlier is mutual, the output will be realized if the specified resources are available at the specified time. Many organization violate the mutuality, demanding the output in

Figure 6 visualizes the refinement from roadmap, via budget to detailed plan. Roadmapping is a yearly cycle, performed in burstmode. The yearly budget, with the associated product plans, are derived from the roadmap, but supported by bottom up plans. Budgets need a more frequent review and maintenance process, most often this happens in a quarterly rythm.

The detailed plans, which are part of the product generation process, are the short term means to control the development. These plans change quite rapidly, driven by (small) marketing and technical events.

As reminder for the control minded people:

Development is the art of managing uncertainties.

Roadmaps will never come true, they serve the purpose of showing trends and uncertainties, to enable the management of these uncertainties.

Budgets are a means to avoid nasty surprises. Budgets and plans must be feasible and believable to generate the required commitment.

6 The System Architecture Process

The System Architecture Process bridges the Policy and Planning Process and the Product Creation Process. The roadmaps made in the policy and planning process are the shared understanding of direction of the company:

- It positions the products in the market and within the product portfolio.
- It shows the relations between products, such as re-use of technology.
- It positions the product in the technology lifecycle.
- It relates products and technology to the (long lead) development op people and process

The System Architecture Process is the process that:

- Gathers input for the Policy and Planning Process
- Brings in technical overview and common sense in the Policy and Planning Process and the Product Creation Process
- Transfers the intention of the Policy and Planning Process into the Product Creation Process

time, without providing the resources in time. This practice breeds evading behaviour, undermining any process.

- Performs the system level Requirement analysis, Specification, Design and Verification
- Maintains the consistency, integrity and balance.

Besides roadmaps the System Architecture Process can make use of a reference architecture to bridge the two processes. A reference architecture abstracts the essential characteristics from 5 different views, see figure 7. This abstraction enables it to be used over the entire domain. The trends can often be explained more easily in this abstraction than in the detailed reality of the current product.

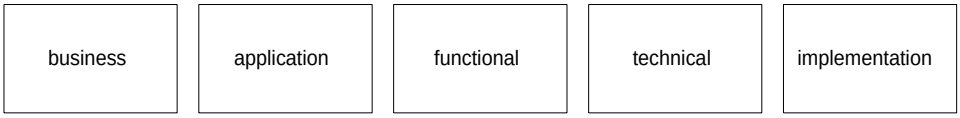

Figure 7: A Reference Architecture covers 5 different views

It is important to realize that the System Architecture Process spans all 5 views. The system architect strives towards a healthy consistent and balanced relationship between these 5 views.

The 5 views consolidate know how by abstracting the invariant, or slowly varying, information in the reference architecture. Note that in general the left hand side (business, application) varies slower than the right hand side. The implementation varies quite fast with the current technology developments. The reference architecture with respect to the implementation identifies critical implementation issues and potential paradigm shifts.

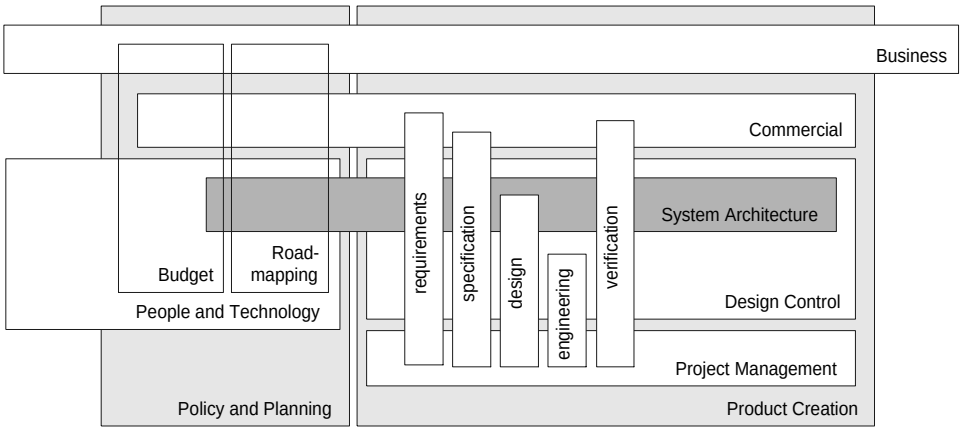

Figure 8: Map of the system Architecture Process and neighbour processes

A map of the processes mentioned so far is shown in figure 8. This map clearly shows the many relationships between processes. This map is only a very small

subset of the process map of an entire business. To keep this map accessible even processes which have a relation with the system architecture process have been left out, for instance manufacturing engineering, service engineering, quality assurance etcetera.

References

[1] Incose. International council of system engineering. URL: http://www.incose.org/toc.html, 1999. INCOSE publishes many interesting articles about system engineering.

[2] Ivar Jacobson, Grady Booch, and James Rumbaugh. *The Unified Software Development Process*. Addison-Wesley, Reading, MA, 1999.

[3] Klaus Kronlöf, editor. *Method Integration; Concepts and Case Studies*. Wiley, Chichester, England, 1993. a useful introduction is given in Chapter 1, The Concept of Method Integration.

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[5] Gerrit Muller. The product creation process. URL: http://www.extra.research.philips.com/natlab/sysarch/index.html, 1999.

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[7] Eberhardt Rechtin and Mark W. Maier. *The Art of Systems Architecting*. CRC Press, Boca Raton, Florida, 1997.

7 Acknowledgements

Discussions with and critical comments from Rard de Leeuw, Jürgen Müller, Henk Obbink, Ben Pronk and Jan Statius Muller helped to shape this article, to improve its structure and to sharpen the contents. I am grateful for their contribution.

History

Version: 2.4, date: february 23 2000 changed by: Gerrit Muller

- Figures updated for readability
- End of life of this article announced in introduction

Version: 2.3, date: october 25 1999 changed by: Gerrit Muller

- Changed the reference to the System Architecture HomePage
- Introduced the Gaudí project.
- Product Creation Process:
  - Added paragraph about concurrency and the need for feedback
  - Added reference to Unified Process
- standard footer added
- updated internal generation structure

Version: 2.2, date: october 1 1999 changed by: Gerrit Muller

- Figures updated to make them re-usable for slide-presentations.

Version: 2.1, date: september 6 1999 changed by: Gerrit Muller

- Introduction:
  - refined phrasing
  - added a paragraph to explain the structure of the article
- What is a process:
  - refined and extended phrasing
  - refinement of terminology (a.o. "method" replaced by "structure" and "rationale")
  - added a citation to the book "Method Integration"
  - added the figure Process Abstraction Hierarchy
  - added a sentence about organization models
  - added a sentence about people in relation with process
- Process Decomposition
  - Added introductory sentence
  - Refined phrasing
  - Added a paragraph discussing shortly the architect function in different scopes.
- Product Creation Process
  - changed the sequence "design, verification, engineering" in "design, engineering, verification"
- Policy and Planning Process:
  - In the figure visualized the boundary between Policy and Planning Process and Product Creation Process.
  - Added a reference to the reference figure
  - Added a paragraph about the reference architecture and variability
- System Architecture Process
  - Moved the figure one paragraph later.
  - Minor editorial changes
- Acknowledgements: added Juergen Mueller
- History: reversed ordering; most recent changes in larger font.

Version: 2.0, date: september 2 1999 changed by: Gerrit Muller

- Processed review comments of Henk Obbink, Ben Pronk and Jan Statius Muller
- Added the section "Acknowledgements"
- Introduction:
  - added the intended readers
  - added a more specific application area
  - added a sentence about the interchangeability of system architects and team of system architects.
  - added the perspective
- What is a process:
  - "Timing" changed in "Ordering"
  - "to run an organization" changed in "to ensure the effective functioning of an organization"
  - "rules" changed into "means which help to"
  - appended 80/20 text to the last paragraph
- Process Decomposition
  - appended a paragraph explaining the relation of the system architect and the Customer Oriented Process
  - appended a paragraph explaining the relation of the system architect and the People and Technology Management Process
  - appended a paragraph describing the number of instances of each process.
  - appended a paragraph to explain the split up of PCP and policy and planning
  - appended a paragraph to indicate that evolutionary developments are done with the normal full PCP
- Product Creation Process

    - "design control process" changed in "design process"; the name "design control" was used within ASML, in the context of this article "design" is shorter and covers better the meaning intended here.
    - subsection phases: added figure and text about business phases.
- Policy and Planning Process
    - Added an explanation of budgets.
- System Architecture Process: added reference architecture figure and explanation
- bibliography
    - added a reference to the INCOSE homepage

Version: 1.0, date: august 23 1999 changed by: Gerrit Muller

- Start of history change log

Version: 0, date: august 11 1999 changed by: Gerrit Muller

- Under construction, no change log yet.