Tutorial How to Engineer Systems as Start-up or in Disruptive Circumstances?

logo
TBD

Gerrit Muller
USN-SE and TNO-ESI
Hasbergsvei 36 P.O. Box 235, NO-3603 Kongsberg Norway
gaudisite@gmail.com

Abstract

Start-up companies operate in an environment, where their market is not clear, nor their business model. At the same time, the contours of their solutions are still shaping up and the technology, production and delivery process and the supply are all under development. In other words, everything is moving simultaneously. Start-ups need persistence and focus to spend their limited resources well, while they also need to be open minded and responsive to market and business needs. How can start-ups use the systems engineering knowledge in a way that it fits this context?Interestingly, large organizations may have similar needs, when disruptive developments take place. A clear example is defense, where drones and electronic warfare disrupt existing doctrines. This tutorial guides the participants to a highly iterative systems engineering process with the continuous challenge to do just enough. The purpose is to facilitate the required level of responsiveness, while at the same time bring sufficient anticipation of the many enabling systems that need development.

version: 0 status: preliminary draft May 23, 2026

Contents

Chapter 1

Introduction

Chapter 2

Introduction How to Engineer Systems as Start-up or in Disruptive Circumstances?

logo
TBD

2.1 Introduction

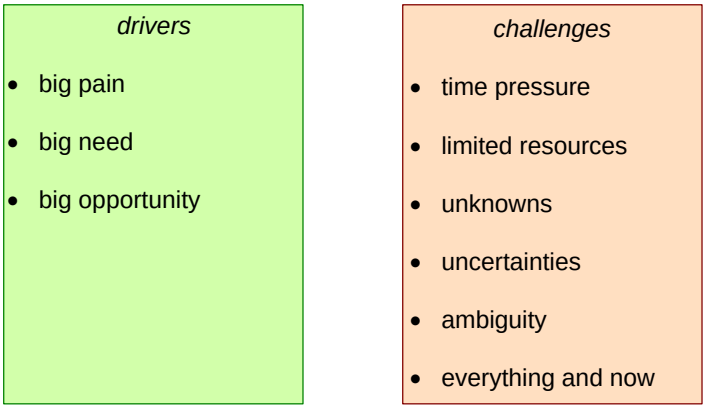
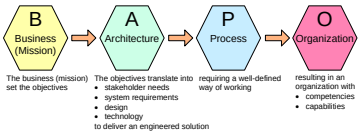


Figure 2.1: Disruptive Change Consequences

Chapter 3

Frameworks for Architecting



3.1 Introduction to frameworks

Figure3.1 shows the frameworks this paper is using.

BAPO is the overarching framework, connecting Business, Architecture, Process, and Organization

Quadruplet elaborating Business and Archiyecture

The social to technical aspects elaboratng Process and Organization

3.2 The BAPO framework

BAPO stands for Business, Architecture, Process, and Organization. The order of these views is relevant:

- The Business drives the architecture that guides the engineered solution.
- The architecture requires a suitable way of working, which is captured in the processes.
- The processes fit in an organization with capabilities and requires individuals with specific competences.

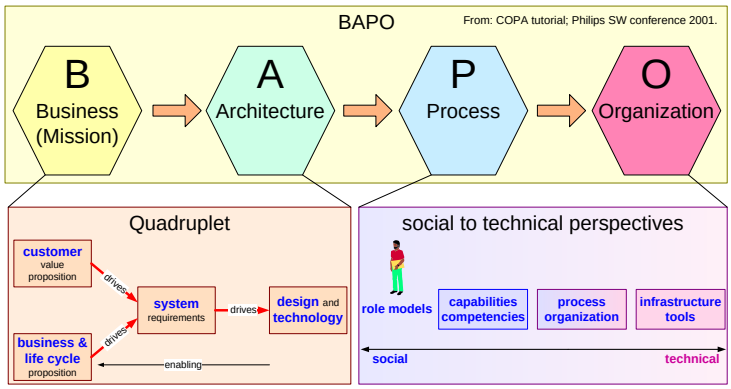


Figure 3.1: Frameworks for Architecting

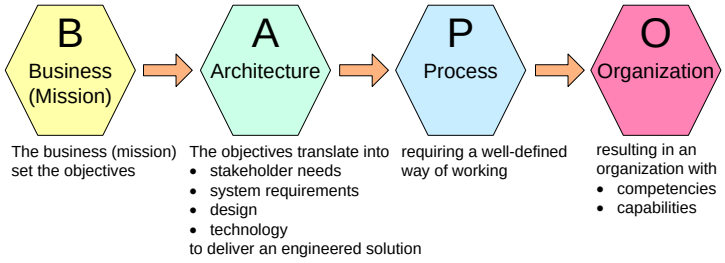


Figure 3.2: The Encompassing BAPO Framework

Figure3.2 shows the BAPO framework.

Obbink et al. [4] created the BAPO framework. Later Henk Obbink suggested extending the framework to BAPOC by adding Culture as additional view. The thinking behind adding culture is that culture has much impact on individual and organizational behavior. Culture is challenging to change, which takes energy and time. Changing process and organization may seem easier, however, culture may limit its effect.

When using the framework in the defense domain, the term business is ill-fitting. In defense a term like mission or main task, capturing the main objective of defense is more suitable.

3.3 The quadruplet framework for architecture descriptions

The quadruplet is a framework to guide the creation and capturing of architecture descriptions. The core of the framework is that the customer value and the business

and lifecycle propositions drive the definition of the system, which in turn drives the design and technology choices. Figure3.3 shows the quadruplet framework.

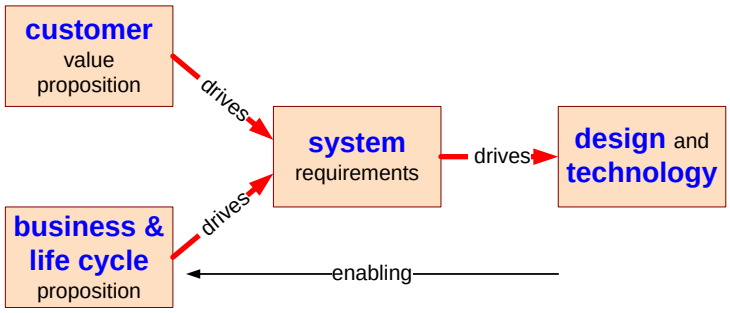


Figure 3.3: The Customer and Business Propositions are Driving

The quadruplet framework is building on the CAFCR+ framework; see[3]:

- The CA-views map on the customer value proposition.
- The F-view maps on the system requirements.
- The CR-views map on the design and technology
- The +-view maps on the business and life cycle.

The quadruplet simplifies CAFCR+ by combining C and A, and C and R views. The simplification helps in some of the ways of using the framework. The adapted visualization order expresses the driving logic better. This improved order balances the customer and business and lifecycle propositions better.

3.4 A framework covering the spectrum social-technical

Figure 3.4 shows a spectrum from social to technical with 4 main views:

Role models are essential to help people copying desired behavior

Capabilities and competencies that need development. Organizational capabilities build upon individual competencies. A capable team is more than a group of competent indidduals.

Process and organization is the structure that we agree upon to work together. Processes are the dynamic behavior, while the organization is the static structure, e.g. what groups with what relations.

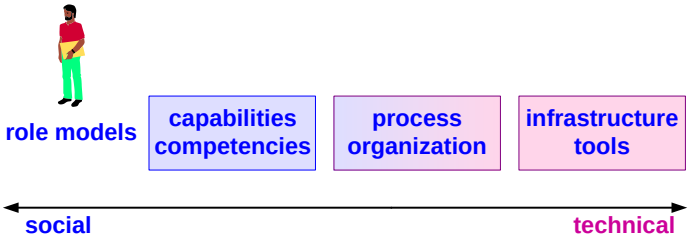


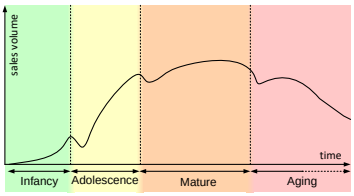
Figure 3.4: Change Requires Addressing the Full Spectrum

Infrastructure and tools Infrastructure and tools form the most technical components. They support the processes and organization to enable the desired capabilities.

The framework showing a spectrum from social to technical finds it origin in change and transformation programs. Organizational transformations require attention over the full spectrum from social to technical. This may seem obvious, however, I have seen amazingly many transformations addressing only one of these views.

Chapter 4

Market Product Life Cycle Consequences for Architecting



4.1 Introduction

A class of products serving a specific market evolves over time. This evolution is reflected in the sales volume of these products. The systems architecting approach depends where products are in this evolution.

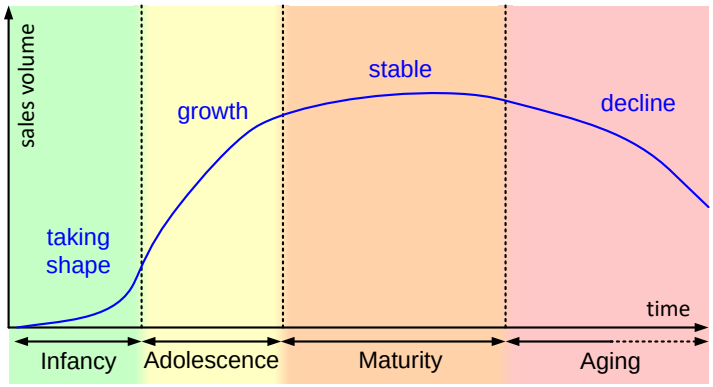


Figure 4.1: Compared with ideal bathtub curve

The life cycle of a product market combination can be visualized by showing the sales volume as a function of the time. In literature the form of the curve of the sales volume as function of the time is described as bathtub, see figure 4.1. It is customary to recognize four phases in this curve:

- The life cycle starts with very small sales in the **infancy** phase, where the product finds its shape.
- A fast increasing sales volume in the **adolescent phase**.
- A more or less stable sales volume in the **mature** phase.
- A decreasing sales volume in the **aging** phase.

The curve and its phases represent the theoretical evolution. In the next paragraphs we will discuss observations in practice and an explanation, and we will show that the class of products and the market themselves also evolve on a macro scale.

4.2 Observed Life Cycle Curve in Practice

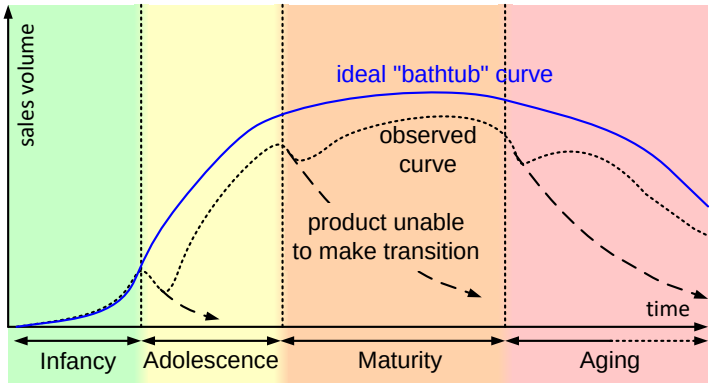


Figure 4.2: Market product life cycle phases

Henk Obbink (Philips Research) observed dips in the sales volume, as shown in figure 4.2. The transition from one phase to the next does not seem to happen smoothly. In some cases the sales drops further and the product does not make the transition at all.

The hypothesis for the dips in the curve is that characteristics of all stakeholders are different for the different life cycle phases. If the way of working of an organization is not adopted to these changes, then a mismatch with the changed circumstances results in decreasing sales. Figure 4.2 also indicates that, if no adaptation to

the change takes place, that the sales might even drop to zero. Zero sales effectively is killing the business, while still plenty of market opportunity is present.

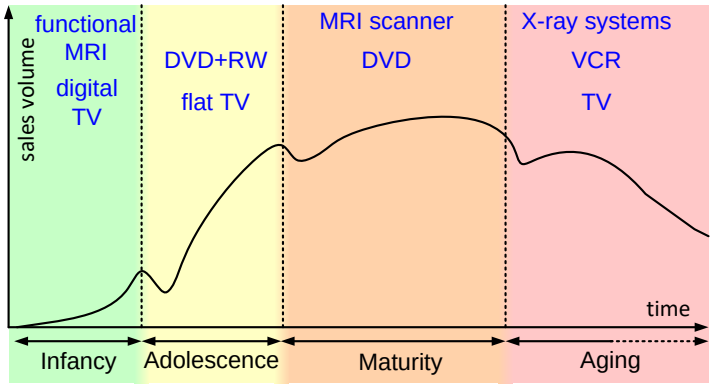


Figure 4.3: Examples of product classes on the curve

Figure 4.3 annotates the life cycle graph with a number of products and their positioning in the life cycle. As can be seen products can move backwards in the phases (i.e. become "younger") by the addition of innovative features. For instance MRS scanners moved backwards when *functional imaging* was added, an innovative way to visualize the activity of specific tissues. Similarly, conventional televisions rejuvenated multiple times by adding digital processing, flat screens, and digital interfaces.

4.3 Life Cycle Model

Figure 4.4 shows typical attributes of the life cycle phases.

The *infancy* phase is characterized by uncertainty about the customer needs, and therefore the product requirements. Essential is that the creator/producer is responsive to the customer needs, which will provide insight in needs and requirements. The way of working in this phase reflects the inherent uncertainty, the chaotic development, and the innovative and pioneering mind set. Product cost is still less of an issue, the risk related to the uncertainty is the dominant concern. The design copes with the uncertainty by over-dimensioning those aspects which are perceived to be the most uncertain.

The *adolescent* phase is characterized by strong (exponential) growth of the sales volume, concurrent with an increase in performance, features and product variants. The challenge is to cope with this strong growth in many dimensions. With respect to the requirements a strategic selection is needed, to serve the growing customer base, without drowning in an exploding complexity. The technical and process challenge is to scale up in all dimensions at the same time. Up-scaling

	Infancy	Adolescence	Mature	Ageing
Driving factor	Business vision		Stable business model	Harvesting of assets
Value from	Responsiveness	Features	Refinements / service	Refining existing assets
Requirements	Discovery	Select strategic	Prioritize	Low effort high value only
Dominant technical concerns	Feasibility	Scaling	Legacy Obsolescence	Lack of product knowledge Low effort for obsolete technologies
Type of people	Inventors & pioneers	Few inventors & pioneers "designers"	"Engineers"	"Maintainers"
Process	Chaotic		Bureaucratic	Budget driven
Dominant pattern	Overdimensioning	Conservative expansion	Midlife refactoring	UI gadgets

Figure 4.4: Attributes per phase

the Customer Oriented Processes and the Product Creation Process requires more shared structure between the participants. This involves a mind set change: less inventors, more designers. The design pattern used frequently in this phase is conservative extension of a base design.

The *mature* phase is characterized by more stability of the business model and the market, while the market has become much more cost sensitive. Instead of running along in the feature race more attention is required to optimize the specification and development choices. The value can be shifting from the core product itself to services and complements of the product, while the features of the product are mostly refined. The age of the product starts to interfere with the business, obsolescence problems occur, as well as legacy problems. Innovative contributions become counterproductive, more rigid engineers are preferred above creative designers. The cost optimization is obtained by process optimization, where the processes also become much more rigid, but also more predictable, controllable and executable by a large community of less educated engineers. The design copes with the aging technology by performing limited refactoring activities in areas where return on investment is still likely.

The *aging* phase is often the phase where the product is entirely seen as cash cow, maximize the return on (low) investments. This is done by searching all the low effort high value requirements, resulting mostly in small refinements to the existing product. Often the integral product know how and even specialist know how has been lost. Only very important obsolescence problems are tackled. Again the mind set of the people working on the product is changing to become more maintenance oriented. Cost is a very dominating concern, budgets are used to

control the cost. Many changes are cosmetic or superficial, taking place in the most visible parts of the product: the user interface and the outer packaging.

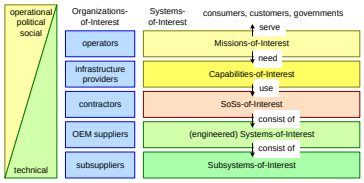
4.4 Acknowledgements

Henk Obbink observed the discontinuity of market success at the phase transitions. The analysis of this phenomenon was carried out by Jürgen Müller, Henk Obbink and Gerrit Muller.

Pierre America improved the layout of the diagrams.

Chapter 5

Introduction to Ecosystems



5.1 Introduction

Capabilities and services that we use at societal level are the result the work of many organizations. We simplify the classification of the organizations contributing to the capabilities and services to a 5 layer model, as Figure 5.1 shows. The five layers are

- operators delivering the actual capabilities
- infrastructure providers that manage the assets that the operators are using
- contractors that build, adapt, and integrate the systems of system that together form the infrastructure
- Original Equipment Manufacturers (OEM) suppliers that develop individual systems that the contractors further integrate
- sub-suppliers developing and delivering products and components to the OEM suppliers

The way of procuring from layer to layer shifts from an acquisition of solutions gradually into procurement of standardized catalogue products and components.

The focus per layer is shifting. Figure 5.2 shows the focus per layer. The higher the layers, the more operational, the deeper in the stack, the more technical

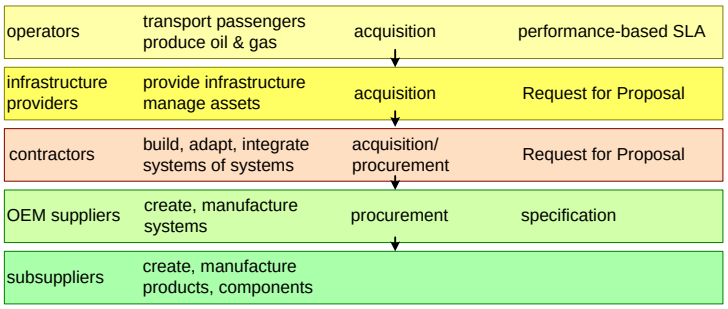


Figure 5.1: Characterization of Domain Layers

the focus becomes. The figure shows a few examples from the rail transportation domain. Operators are inherently operationally oriented. Examples are operators in The Netherlands, such as NS and Arriva. Infrastructure operators are asset oriented. ProRail is in the Netherlands responsible for the rail infrastructure with a worth of many Billions with a yearly turnover close to 2 billion Euro. Contractors are construction project oriented. OEM suppliers have a development project or product focus, while sub-suppliers have a product or component focus. Companies may operate at multiple levels, although these tend to organizationally fit in different silos in that company.

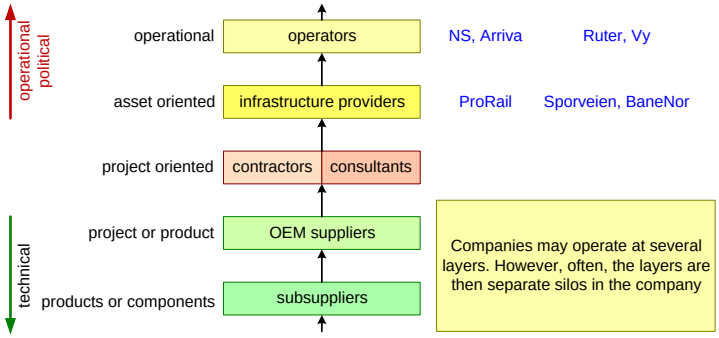


Figure 5.2: Positions in the Value Network Differ in Nature

Figure 5.3 summarizes these layers in terms of the organizations-of-interest and systems-of-interest: Operators serve consumers, customers, and governments with missions-of-interest. Operators need capabilities-of-interest that infrastructure providers provide, using SoSs-of-interest that operators deliver. The SoSs consist of (engineered) systems and SoSs that OEM suppliers develop and deliver. Sub-suppliers develop and deliver the subsystems-of-interest. High in the layers, the main concerns are

operational, political, and social, while deep in the layers, the main concern is technical. Economic and legal concerns play in all layers.

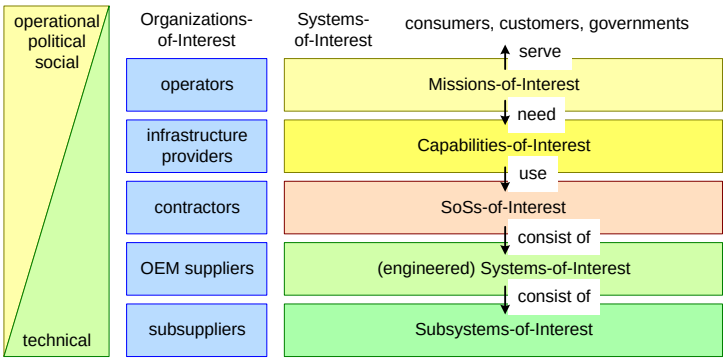


Figure 5.3: Perspective Changes from Layer to Layer

5.2 Enabling systems

Systems engineering teaches us that when we develop a system-of-interest (SoI), that we then also have to develop the related enabling systems. Figure 5.4 shows some examples of enabling systems, such as the manufacturing, transportation, installation and training systems. This list is far from complete. An essential enabling system is the entire supply chain, including its supporting structures, such as contracts, second suppliers, et cetera.

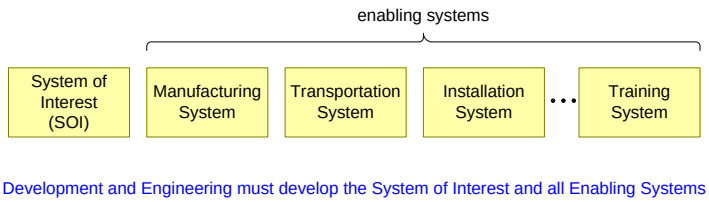


Figure 5.4: Development Has to Develop the System of Interest and its Enabling Systems

This applies recursively for each system when going down in the layers of the ecosystem.

5.3 Scope of Control

When developing products and components, the developing organization has more or less full control over the specification and design of the product. This changes fundamentally when we enter the Systems-of-Systems domain. SoSs inherently are independent, so, the SoS constructor and users don't have full control. The less cohesion there is between constituent systems in managerial sense, the lower the influence is anyone within the ecosystem has.

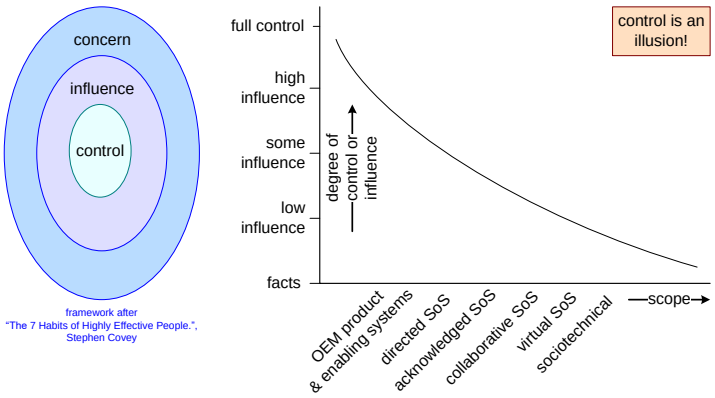


Figure 5.5: The Level of Influence Decreases with Scope

[1] provides a simple framework with a scope of control, a scope of influence, and a sphere of concern. Figure 5.5 shows the simple framework. The graph uses a more continuous scale on the vertical axis for the degree of influence. Be aware that full control is an illusion. The horizontal axis defines the system scope from small to large, also as continuum.

5.4 Layers of Ecosystems

Each layer of Figure 5.3 consists of an ecosystem itself. Figure 5.6 shows an elaboration of these layers. For example, an OEM company has suppliers (with their suppliers), partners offering complementary products and complmenting services and systems. The OEM company will have competitors. Most of these organizations will interact with the customers of the OEM company, such as the contractor.

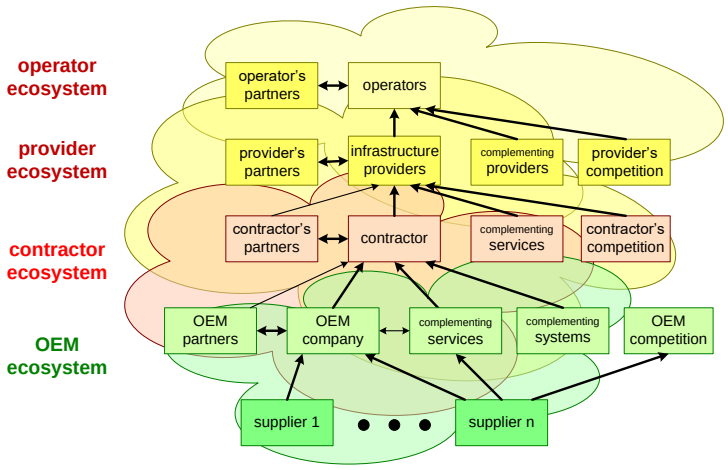


Figure 5.6: Each System and organization is part of its ecosystem

Bibliography

[1] Stephen R. Covey. *The 7 habits of highly effective people: restoring the character ethic*. Free Press, New York, rev. ed. edition, 2004.

[2] Gerrit Muller. The system architecture homepage. `http://www.gaudisite.nl/index.html`, 1999.

[3] Gerrit Muller. CAFCR: A multi-view method for embedded systems architecting: Balancing genericity and specificity. `http://www.gaudisite.nl/ThesisBook.pdf`, 2004.

[4] Henk Obbink, Jürgen Müller, Pierre America, and Rob van Ommering. COPA: A component-oriented platform architecting method for families of software-intensive electronic products. `http://www.hitech-projects.com/SAE/COPA/COPA_Tutorial.pdf`, 2000.

History

Version: 0, date: May 9, 2026 changed by: Gerrit Muller

- Created, using material from MarketProductLifecycle, FromSystemToEcosystem, StakeholdersFromAbstractToHumans, SystemModelingAndAnalysis.