MASTER

Reference architecture creation

creating insight in the product creation process of Philips Consumer Electronics

America, F.M.

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Master Thesis

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PHILIPS

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Abstract

This study is about creating insight in the Reference Architecture Creation process in the Product Creation Process of Philips Consumer Electronics. It results in a reference model that is designed and validated and that could be used by system architects as a practical guideline and project life cycle model. Common terminology is used to standardize this process in Philips CE.

Management Summary

This is the management summary of the master thesis of the study Industrial Engineering and Management Science, Eindhoven, University of Technology, carried out at Philips Consumer Electronics Mainstream, Technology & Development, PCP-office.

Philips Consumer Electronics
Philips Consumer Electronics is a division of Royal Philips Electronics NV It is a company in the Electronics sector. Gerard Philips has founded Royal Philips Electronics NV in 1891. Royal Philips Electronics NV with sales of EUR 32.3 billion in 2001, has 189,000 employees, which are active in more than 60 countries in the areas of:

- Consumer Electronics,
- Lighting,
- Domestic appliances and Personal Care,
- Semiconductors,
- Medical systems.

Royal Philips Electronics NV is quoted on the NYSE (symbol: PHG), London, Frankfurt, Amsterdam and other stock exchanges.

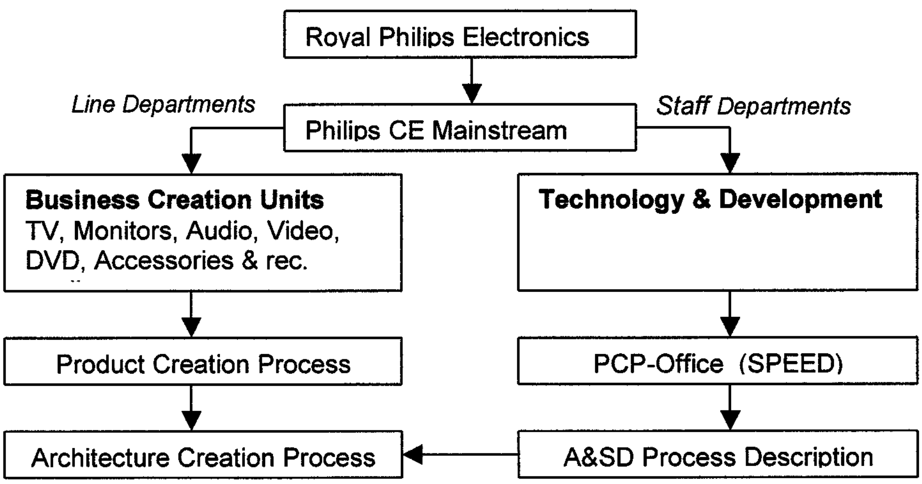

Figure A: Graduation context

Following Figure A, the graduation project took place on behalf of the PCP-Office. This belongs to the Staff department Technology & Development. PCP-Office supports the Business Creation Teams in improving their Product Creation Process and to achieve an optimum in commonality in these processes over the different Business Creation Units of Philips Consumer Electronics Mainstream. This results in a general process description called SPEED. One part of the SPEED process model that will be the focus of this graduation project is the Architecture & Standard Design Creation Process.

Reference Architecture is:

- The arrangement of functions,
- The mapping of functions to physical standard designs and
- The specification of the interfaces among the interacting physical standard designs.

Reference architecture affects how variety is established within production; how change can be realized across subsequent generations of products; how designs can be standardized; the overall performance of products and the management of product development.
Reference architecture impacts on product development, product variants, quality (testing), purchasing and after sales.

Problem
As described in chapter 2, this research started with a problem analysis and the following problem is ascertained:

Philips CE thinks that it is running behind in managing reference architecture creation processes and therefore insight in the reference architecture process is needed.
Due to the change in business environment, Philips CE is confronted with a rapidly increasing complexity in almost all aspects of the Product Creation Process (PCP) and due to the current internal PDM and Filocity projects the following questions were derived:

- Product Data Management (PDM) is a tool that helps engineers and others manage both data and product development processes. PDM systems keep track of the masses of data and information required to design, manufacture or build, and then support and maintains products. PDM is intended to support the entire product lifecycle and to facilitate integration between following product related lifecycles in an enterprise: Product Definition, Product Realization, Product Manufacturing, and Servicing & Customer Support. *Could architects include data as early as possible in the PDM-system?*

- The Filocity project is intended to implement a new supply chain planning process and is an initiative of the Supply Chain Management. The goal of Filocity 'New Product Introduction' process is: To have a full business plan with all types of components and their forecasted quantities for a 18 months horizon To prevent constraints for critical components by giving orientations of component requirements towards suppliers also with a horizon of 18 months. *Could architects give a forecast of key components in the most early phase?*

The following research questions are defined:

1. *What is a more detailed process description of the reference architecture creation made in the different parts of Philips CE and what process activities could be executed with support of the Product Data Management system, without extra effort of the Architects?*
2. *What are the most adequate moments in time during the reference architecture creation process to include, data about key components, the physical view, the functional view and the requirements view of the reference architecture in the Product Data Management system?*

To give answers to those questions the following assignment is defined:

Create a process description, (practical guideline, project life cycle models and common terminology) of reference architecture creation that standardizes this process in Philips CE.

The goal of research for Philips CE is to get better insight in the process of reference architecture creation. With this insight Philips CE wants:

- to predict key components that are needed in an earlier phase.
- to include information about the reference architecture in the PDM system at an adequate moment
- to get insight how to control the diversity of products with reference architectures.

Theory
Given the assignment it's necessary to get insight in theoretical models. Models for reference architecture creation process can be found in literature and other sources. The starting point is the reference architecture creation process of the PCP office. This process model will be extended with more detailed process steps discussed in several models out of the literature (Theory). Very extensive, because we want to include activities as much as possible. This

together forms an improved model, the reference model 1. An analysis about the theoretical models is given at the end of chapter 3.

Architecture can be defined as: The highest-level concept of a system in its environment. The scope of this environment could be different. In paragraph 3.2.4 the hierarchy of architectural scopes is explained. An architectural description is a model (document, drawing, product or other artifact). An architectural description conveys a set of views each of which depicts the system by describing domain concerns. The goal of architecting is to structure the system as good as possible, The goal of architecture description is to communicate and record this structure.

Architecting is both an art and a science – synthesis and analysis, induction and deduction, and conceptualization and certification – using guidelines from its art and methods from its science. It strives for fit, balance, and compromise among the tensions of client's needs and resources, technology, and multiple stakeholder interest.

The following theoretical models have been studied:

- The Waterfall model (Royce, 1970)
- The Win-Win Spiral Process (Barry Boehm, 1998)
- The Rational Unified Process (Rational University and partners, 2000)
- Software reuse, Architecture, process and organization for business success (Ivar Jacobson, Martin Griss, Patrik Jonsson, 1997)
- System Engineering guidebook (James N. Martin, 1997)
- Capability Maturity Model Integration v:1.1 (SEI, 2002)

Case studies
To validate reference model 1, the analysis of three representative case studies within Philips CE and Lighting is described in chapter 4. Feedback will be delivered from the Jaguar project (Up-market TV), the DVD+RW project (Audio) and the TL5 project at Philips Lighting. In the end of each case, results are given. This feedback and results has improved and upgraded the reference model 1, into the reference model 2 and has given some insights.

Insights
So beside this updated reference model 2, at least the following insights are given.
The type of process that results in an architecture of a product family is at least dependant of three variables. A different process should be planned and walked through for each kind of configuration. To estimate how much effort a project will take, these variables should be taken into account. Experience and vision how to plan this process is vital for system architects.

1. There should be a clear distinction between first of a kind, second generation and third generation of architectures. In a first of a kind project innovation is radical and in the second and third generation it is more incremental. In the first case most of the things should be developed from scratch in the second case reuse of data and know-how is possible and because of experience risks are better foreseen.
2. Important is the abstraction level of the architectures or in other words the specification level. Will it only support the main issues? How detailed should activities be worked out? 'Over' specification leads to costs in the beginning. 'Under' specification leads to mistakes that will cost in the end. Somewhere in this trade off there is an optimum.
3. Also the scope of the architectures matters for determining the approach. Will the architecture cover one product or a whole product line? Is the architecture for products, or also processes and markets? In each approach, different aspects will be important.

The process should be flexible to solve issues (e.g. new functionalities, variety in design, cost down measures) Through the pressure of time, architects are forced to make decisions quickly. Architects should therefore use a prioritized list of issues to be solved. Dependant of this list the planning of the process should be made. First the most important decisions should be taken.

If the process could be characterized as “first of a kind”, than the process is focused to be the first on the market. Speed will be the biggest driver. Because the earlier at the market, the bigger the margins. In marketing terminology you could speak of a potential “star”.
If the process could be characterized as “third generation”, than the process is focused to fulfill as much as possible on market needs against a low price. Cost saving will be the biggest driver. Diversity will be another main issue. In marketing terminology you could speak of a “cash cow”.

During the process, the architecture should be worked-out in such a way that it forms a stable base for developing and manufacturing a whole family of products. This requires that at the end of this phase, for all the critical functions of the architecture, the key choices of the whole global range of applications have been established and the supply base has been frozen.
This may require extensive effort from some key suppliers in R&D and manufacturing skills. Joint identification of potential risks in the cross-functional project team, and a striving for a joint business win-win must be part of this process. Wrong supplier choices made in this phase can only be rectified by enormous costs afterwards.

Implementation
The final reference model and the insights provide a good base for supporting and improving the processes. Important for a good implementation is a sound planning and the support of its actors.

System architects and project owners are the persons who could make a selection out of the activities. System architects are the persons with up to date knowledge and have the best experience to select activities. System architects know what things should be done to reach the business goals. For this reason all responsibility is in hands of a team around these persons. The reference model is a detailed and comprehensive process model that could be used immediately and easily.

Planning activities should be done by system architects too. Architects have the experience to estimate how sound in what time and in what order activities could be done best. Planning is strongly dependant of the project that is in account and therefore different in each other situation. People with long experience and the right knowledge have the best intuition to make a planning. Support for the planning is created by consensus. This could be created by good communication and clear appointments in the start of the project. Project management rules and guidelines are very useful in situations like this.

One of the tasks of the PCP-office is to stimulate the use of this reference model. This could be realized first by publishing the reference model in the Architecture and Standard Design Process brochure[2] and secondly give feedback after audits that are done. Stimulation of architects and promotion of the reference model should be done constantly and consequently.

Conclusions
The conclusion of the assignment that has been defined in chapter 2 is as follow:

A reference model has been developed and validated for the reference architecture creation process. This reference model is more detailed than the initial process out of the SPEED documents. Also common terminology is created.

The reference model was constructed by looking to theoretical models in chapter 3 and has been validated by three case studies representative for Philips CE. Case studies were described in chapter 4.

To complete the answer of the first research question on a detailed process description and what activities could be executed with support of the PDM system, the following is concluded.

Architects themselves could decide best whether activities can be executed with support of the product data management system or not.

To answer the second research question on the most adequate moments in time to include data in PDM, the following is concluded.

The most adequate moments to include data about key components, physical view, functional view and requirements view of the reference architecture in a product data management system is different in each certain situation and should be decided by the architects themselves for that certain situation.

The literature described in chapter 3 and the three case study's described in chapter 4 delivered extra valuable insight in the context of the process and different aspects of architecting.

Recommendations

Recommendations for architects

- Use the reference model!
- Study, analyze and select the activities of the reference model
- Maintain and Improve Terminology
- Check for different projects where and how many milestones should be set
- Let system architects decide the moment whether or not information should be included in the Product Data Management system
- Clear viewpoints and views should be developed in detail.
- Architects should document information of related matters of reference architectures.
- Jaguar architects should improve the process model in Appendix G.

Recommendations for PCP-Office

PCP-office should

- motivate system architects by using the reference model
- test the reference model
- maintain the reference model
- get feedback from architects and Maintain and Improve Terminology
- Document insights out of feed-back and audits of the future projects.
- support future and further research on this field but this should be initiated by the BCU or department where the process takes place.

Preface

I started the graduation project in February 2002 full of enthusiasm. I was inspired by the term early adapters. So after puzzling I had decided to have some experience in the product development and innovation field. This is the field where you could learn and influence what is going to happen in the future. I had convinced myself to have some experience in a big company, after I had some projects in companies below the 200 employees. After a short introduction at Philips CE, I decided to start the project here.

As most graduation projects I could say afterwards that succeeding this project was more difficult than I thought in advance. But mostly the less easier a project is the more you learn. Though the subject was abstract and difficult, I was in the belief I could only learn from it.

Indeed, I learned from it. There were some things I didn't know in advance.

- To graduate on a staff department is not an effective way to get results.
- Trying to do everything yourself does not deliver the wanted solutions
- Plans are nothing, planning is everything
- Doing more things in a time makes you crazy

In the end I think the project delivered some successful points. Good insights are given and some models could be useful in the future. Nonetheless, I was surprised by the patience of my coaches. Many obstacles were taken with great help of these coaches. I was very glad with the motivation and inspiration they gave during this 15 month lasting adventure.

I see this graduation report as a milestone of my life. Also here you don't know what is coming at your road. You cannot predict the future. I trust I can use this experience in the future. We will see!

Frederik America

Content

1 Philips Consumer Electronics

1.1 Royal Philips Electronics N.V.

Philips Consumer Electronics is a division of Royal Philips Electronics N.V. It is a company in the Electronics sector. Gerard Philips has founded Royal Philips Electronics N.V. in 1891. Royal Philips Electronics N.V. with sales of EUR 32.3 billion in 2001, has 189,000 employees, which are active in more than 60 countries in the areas of:

- Consumer Electronics,
- Lighting,
- Domestic appliances and Personal Care,
- Semiconductors,
- Medical systems.

Royal Philips Electronics N.V. is quoted on the NYSE (symbol: PHG), London, Frankfurt, Amsterdam and other stock exchanges.

Division of sales in Royal Philips Electronics N.V. (see also chart 1.1):

1	38,8%	Consumer Electronics
2	18,9%	Lighting
3	17.8%	Medical Systems
4	15.6%	Semiconductors
5	8.9%	DAP

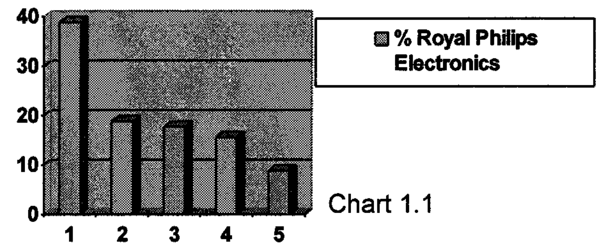

Chart 1.1

1.2. Philips Consumer Electronics

Philips Consumer Electronics is divided into 4 parts. The division of sales in Philips Consumer Electronics is as follow (see also chart 1.2):

1	78%	Mainstream CE
2	11%	Consumer Communications
3	7%	Digital Networks
4	4%	Licenses

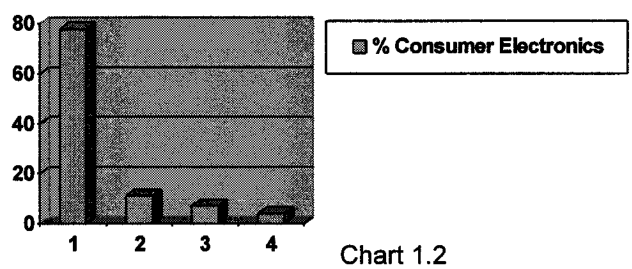

Chart 1.2

The focus of this assignment will be on Mainstream CE. The division of sales in Philips Mainstream CE is (see also chart 1.3):

1	41%	TV
2	23%	Monitor
3	17%	Audio
4	10%	Video
5	9%	DVD, Accessories & rec. media

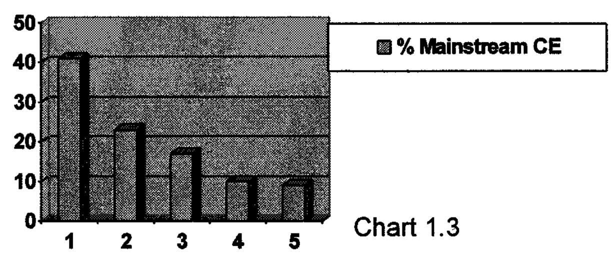

Chart 1.3

Philips Consumer Electronics (PCE) product portfolio includes; video recorders and TV-Video Combis; audio systems, separates, portables and Home Cinema solutions; recording media for audio/video; PC monitors, and PC-peripherals such as DVD+RW data drives, CD-Rewriters, PC video cameras (for sending video mail), LCD projectors and remote control systems for consumer electronics appliances; wide screen television format; flat display TVs; monitors; Optical Disc products including DVD-recorders; Super Audio CD; digital television systems and Internet connected devices such as Internet audio systems; Personal Video Recorders and Universal Serial Bus (USB) equipment. Personal communication products including cellular phones, cordless- and corded phones. Philips Digital Networks is active in the broadcasting-, Internet- and video industry and digital set top boxes.

Other facts and figures:
Philips CE has 60 million consumers. It is active in 4 regions, the sales divided into these regions is as follows: Europe 51%, Latin America 9%, Asia Pacific 14%, Nafta 26%. Philips is a clear example of a multinational and matrix organization.

"Philips is in the process of transforming into a high-growth technology company, building on its technological heritage of over 100 years. In this transformation process, our focus will be on our key areas of technology strengths, in particular in the areas of display, storage, and connectivity. These combined strengths make Philips uniquely placed to become a leader in the digital world. We can add value to the way people experience technology in the digitally connected world." Guy Demuynck, CEO, Philips Consumer Electronics at CeBIT 2002

Philips Consumer Electronics operates in a rapidly changing business environment. The increasing rate of technological change and evolution means that the capabilities offered by the technology multiply at a relentless speed. Customers are demanding a wider variety of products at lower cost and they want almost immediate delivery. Products are becoming more complex, with ever-increasing functionality, yet they have to meet the same or more stringent quality requirements. Increased globalization is resulting in ever-intensified competition. As a consequence processes have to be more efficient and faster.

PCE is now in the process of deverticalization, bringing more focus to product development, sales, marketing and outsourcing manufacturing of products for maturing markets such as the VCR. PCE's portfolio will focus on higher growth opportunities with low tolerance for under performing businesses. The unsatisfactory performance in North America is being tackled by intensifying PCE's customer and market focus there.

Philips CE aims:

- to become the number two player in the global Consumer Electronics market behind Sony and in front of Matsushita Electric;
- to become the "shaper" in the following selected product categories:
    - Analogue & digital display centric products,
    - LCD Monitors,
    - Digital A/V playback and recording,
    - Web-enabled products.
- to be a credible and financially predictable organization;
- to have a balanced regional and a balanced product spread;
- to be a premium brand excelling in "consumer experience".

Business Excellence Goals
To achieve these aims Philips CE set out to create a connected range of high quality products and provide services, that delight their consumers, maximize consumers loyalty, generate a strong brand preference, encourage the full development and use of employees' potential. Philips wants to achieve world-class performance in all key processes, great supplier involvement and a furthering integrated supply chain. Philips wants to meet financial targets consistently, of which the most important are:

- A yearly increasing positive EPR,
- A positive cash flow,
- Growth of Philips CE world value share from 10% to 13% in 2004,
- Achieve at least 10% value share in each Product/Market segment,
- Achieve at least a number 2 position in all regions except Asia Pacific (Japan),
- Beat Matsushita in all regions except Asia Pacific (Japan),
- Make 4% IFO on a sustainable basis,
- 40% RONA (beginning 2002) and double EPR (2001 – 2004).

1.3 Consumer Electronics Organization
1.3.1 Consumer Electronics
This paragraph describes the way Philips CE mainstream is organized.

Following Figure 1.1, Philips Consumer Electronics is in one way divided in 5 Business Creation Units and 3 supporting departments. I.e. TV, Audio, Monitors, Video Systems, Project DVD+RW (=Accessories & Recordable Media) and as supporting departments purchasing, logistics that includes Supply Chain Management (S.C.M.) and Filocity (FIL, mentioned in chapter 2) and Industrial Project Office.
In an other way Philips Consumer Electronics is geographically divided in 4 regions i.e. North America, Asia Pacific & Middle East, Europe, and Latin America.
The whole organization is supported by 5 different divisions i.e. Finance & Accounting, Marketing, Technology & Development, Human Resource Management and Information. This is a clear example of a so-called matrix organization.

The assignment will focus on Business Creation Units (BCU's) where processes take place, but the supporting division Technology & Development is responsible for the assignment.

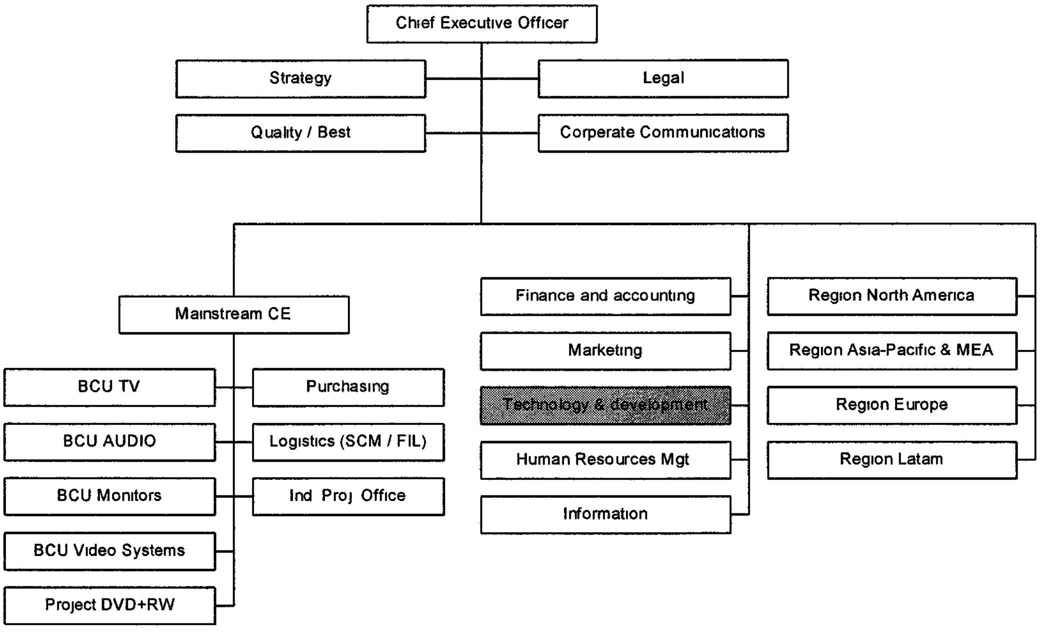

Figure 1.1: Top Level Organization Philips Consumer Electronics.

1.3.2 Technology & Development
T&D takes care of the technologies and developments in know-how planning, programming, and early phase of product realizations (based on SPEED process model). Product Creation Process Office (PCP-office) is part of Technology & Development Division and is responsible for the deployment of the development processes.

As shown in the organization chart of Figure 1.2, the Technology and Development division (T&D) consists of the following areas (left to right):
- The local branch offices, that analyze their markets for new technologies and correspond this to technology architects of the different BCU's .
- The Finance & Accounting and Human Resource Management departments, with focus on the technology and development department.
- The Department of central architects (Architecture/Research); department of display and recording; Department standardization and PCP-office (that defines way of working, evaluate

effectiveness and efficiency of all BCU's product creation processes. In here, the development process support is situated). These groups concentrate how synergy could be made between PCE, other divisions of Philips and other companies. Also worldwide standards are designed.

- The technology and development staff in each different BCU, that analyzes the future technological needs in their business and translate this into actions for the particular BCU.

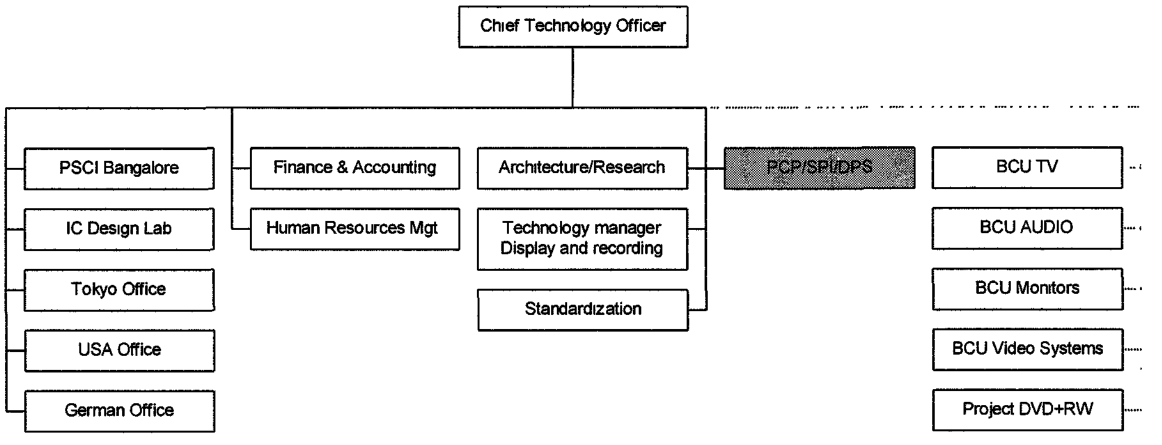

Figure 1.2: Organization chart: Philips CE, Division of Technology & Development.

1.3.3 PCP-Office

The organization of PCP-office is showed in figure 1.3. PCP-office is closely related to the PDM-Office. As mentioned in chapter 2, the PDM-Office is doing a project that has some influence on the assignment. Other departments are Software Project Office (SPO), CAD-Mechanical, Mentor support team and TIM.

The mission of the PCP Office is to support the Business Creation Teams (BCT's) in improving their Product Creation Process and to achieve an optimum in commonality in these processes over the different BCU's of Consumer Electronics (CE).

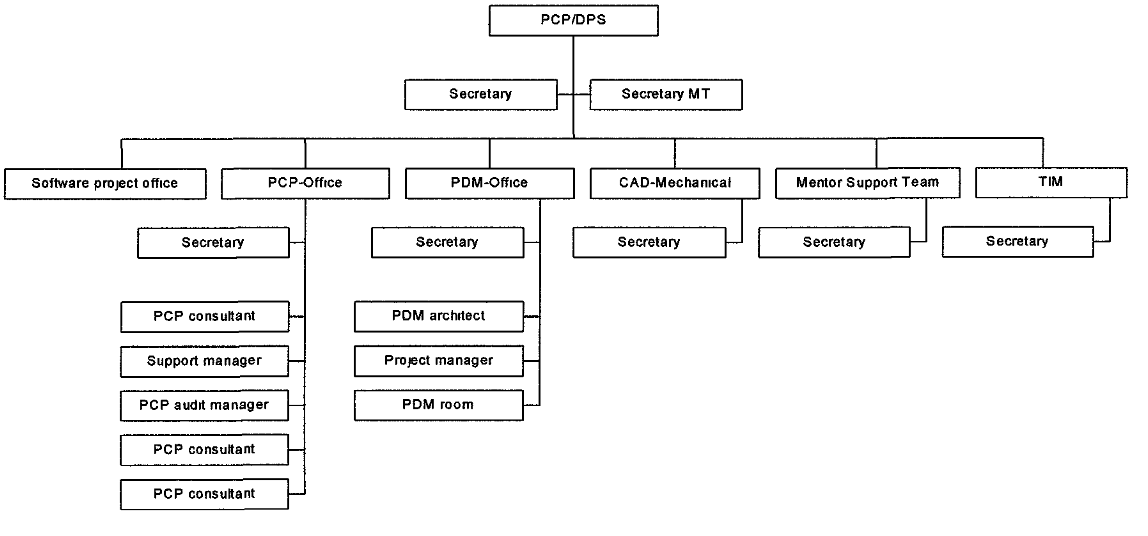

Figure 1.3: Organization chart: Division of Philips CE, Department of T&D, PCP-Office.

Tasks of the PCP Office
In order to implement the mission, the following tasks of the PCP Office can be identified:

- Establish the PCP framework described in appendix 1, to be applied in all BCT's.
- Provide guidelines for different elements of the PCP framework.
- Facilitate the introduction of the PCP framework in the BCT's through consultancy, training, information material, etc.
- Provide a process improvement framework through (self-) assessment methods, checklists, process survey tools (PST's), guidelines for measurement practices, etc.
- Execute assessments on the PCP as a whole and on specific aspects of it.
- Select tools to support (part of) the PCP and initiate/facilitate their introduction.
- Disseminate best practices.
- Monitor the PCP through metrics and performance indicators.

Apart from above process related tasks, individual members of the PCP Office may be involved in operational tasks of the BCT's, based upon their individual expertise. These tasks are always intended to further improve the PCP.

1.4 The Product Creation Process

This paragraph gives insight in the Product Creation Process and especially the Reference Architecture Creation Process, which is prescribed within Philips CE.

1.4.1 SPEED

Philips has a general process description in the product creation phase for each BCU. This process is called SPEED. The SPEED process model is a way to describe the various processes that take place in product creation. The SPEED process is further described in appendix 1.
One part of the SPEED process that will be the focus of this assignment is architecture and standard design creation (A&SD). The reference architecture creation is part of this A&SD phase. A&SD is described in the appendix 1 too.

1.4.2 Reference Architecture Creation

As described in [Oosterman, 2001], product architecture is:

- The arrangement of functions.
- The mapping of functions to physical standard designs.
- The specification of the interfaces among interacting physical standard designs.

The most important characteristic of product architecture is its amount of modularity:
A modular product has one to one mapping between functions and standard designs, and its interfaces are de coupled. An integral product has complex (N-to-M) mapping between the functions and the standard designs, and its interfaces are coupled. In general, products are neither entirely modular nor entirely integral but rather somewhere in between the two extremes. They are called hybrid architectures. As a rule the more the mapping is one to one and the more interfaces are de-coupled the more modular a particular product architecture is.

Why is reference architecture such a crucial issue?
Reference architecture affects how variety is established within production; how change can be realized across subsequent generations of products; how designs can be standardized; the overall performance of products and the management of product development.
Reference architecture impacts on product development, product variants, quality (testing), purchasing and after sales.
Benefits:

- Modular products allow the production of a great variety of end products from a limited number of standard designs
- Modular products allow for a platform strategy permitting a great number of new variants to be developed based on a stable architecture (and few standard designs) Modular products facilitate changes to products once introduced
- Modularity simplifies parallel testing and maintenance
- Modularity allows for parallel development of design teams

- Modularity allows for outsourcing of standard designs
- With today's pressure on business and increasing complexity of products, there is clearly a trend in favor of more modular products. To reduce risks and increase flexibility.

Limitations and drawbacks:

- Too much modularity can make products look alike too much.
- Modularity increases the risk of competitors copying the design
- Modularity is generally at the expense of unit cost and increases the volume (size) or weight of the product
- Modularity may be limited by the technology available
- Designing modular products may be very difficult, be initially time-consuming, and depend on the capabilities of available designers within the company

Studies done by [Henderson and Clark] describe that an established architecture is strongly embedded within the organization and the company's way of working. In addition could be argued that the entire 'knowledge' of a firm is strongly shaped by the architecture of a product. It is reasonable to state that architecture strongly affects and is affected by a firm's strategic considerations, and furthermore heavily influences how the company actually works.

After introducing Philips CE, the PCP-office and giving some insight into the Product Creation Process and Reference Architecture Creation Process, the next chapter will discuss the motivation of this assignment.

2. Problem Description

In this chapter we will define the problem. First the change will be described why the problem appeared. Than the problem itself and next, the assignment and approach will be described how to solve the problem.

2.1 Change

The electronics sector is subject to continuous change of business environment. Change of business environment is often the reason for internal change. In this paragraph the changes are described that have influence on the assignment.

2.1.1 Change drivers

Philips CE is confronted with a rapidly increasing complexity in almost all aspects of the Product Creation Process (PCP). Some of these aspects are:

- Rapidly changing and evolving technology.
- Difficulties to predict technology when technologies become mature.
- Fast changing markets, difficulties to predict market trends.
- Increased organizational complexity (globalization, multi-site, multi-culture).
- Change from hierarchical/functional organization towards networked organization.
- Increased dependencies between technology, market, and organization.
- Stringent targets with respect to lead-time, quality, and financial results.

Increased difficulty in technology is a driver to increase modularity and standardization. Increased consumer requirements is a driver to develop a broader range of products in a shorter time-to-market. Due to the modularity, standardization, broader range of products and pressure on the time-to-market, insight is needed in the process of reference architecture creation (see paragraph 1.4.2).

2.1.2 Projects

Due to the dynamic nature of the business environment Philips CE initiated the Product Data Management (PDM) project and Filocity project. Philips CE organizes projects to increase productivity and efficiency of its processes. These two projects provide questions that affect the assignment. These projects are described in this paragraph.

2.1.1.1 PDM-project

Product Data Management (PDM) is a tool that helps engineers and others manage both data and product development processes. PDM systems keep track of the masses of data and information required to design, manufacture or build, and then support and maintains products. PDM is intended to support the entire product lifecycle and to facilitate integration between following product related lifecycles in an enterprise: Product Definition, Product Realization, Product Manufacturing, and Servicing & Customer Support.

As manufacturing sites become more and more decentralized, PDM as a collaborative technology has tremendous potentials to facilitate teamwork, improve workflow, speed information exchange, and keep the processes running smoothly. Co-ordination and sharing of information in and between the lifecycles is critical to the success of an enterprise.

Within CE, a commercial PDM system will be installed to enable the deployment of the processes as they are defined in the SPEED PCP concept. PDM in CE is integrating the "information generating disciplines" such as EDA (Electrical Design), MCAD (Mechanical Design), SWE (Software Design), Industrial Design into a Design Bill of Material (i.e. eBOM) and interfacing this engineering data at a specific moment in the product creation process towards the different manufacturing sites. Major functions covered by the CE PDM project are document management, configuration management and change management.

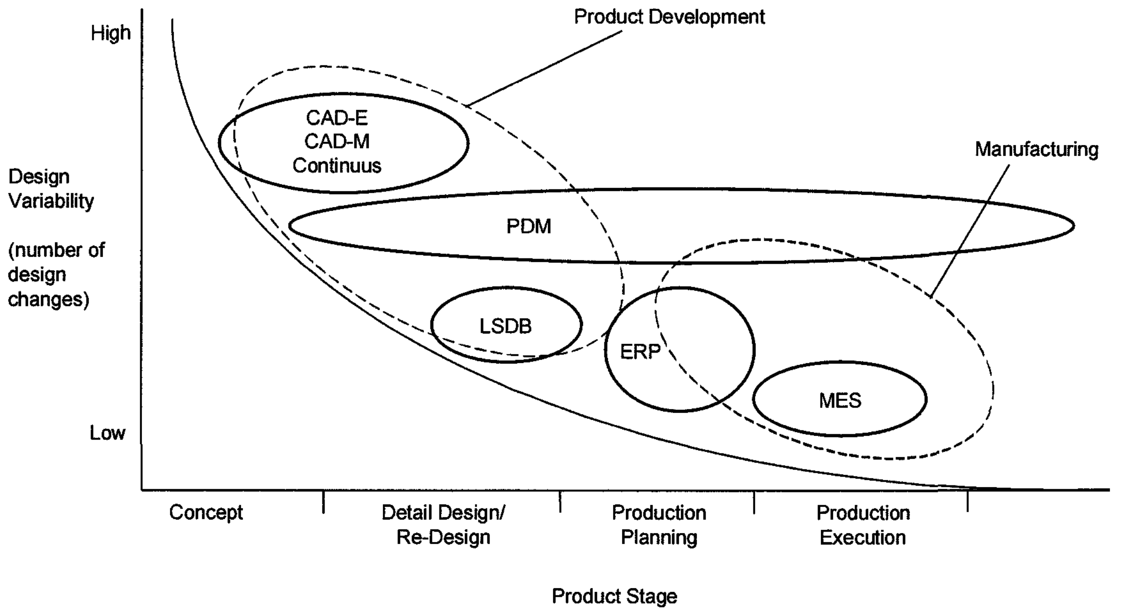

Figure 2.1 - Product data infrastructure

The product data infrastructure showed in Figure 2.1 consists of local authoring environments (CAD-E, CAD-M, and Software Configuration), enterprise product data management (PDM), lightning stroke data base (LSDB), resource planning (ERP) and manufacturing execution systems (MES).

The Trend in Philips CE is to extract information out of its processes from the back-end to the front-end of the organization. Information is already extracted from the product realization phase, In the future reference architecture creation process has to include information in the PDM system. Therefor the next question rises. *Could architects include data as early as possible in the PDM-system?*

2.1.1.2 Filocity project
The Filocity project is intended to implement a new supply chain planning process and is an initiative of the Supply Chain Management. The goal of Filocity 'New Product Introduction' process is:
To have a full business plan with all types of components and their forecasted quantities for a 18 months horizon To prevent constraints for critical components by giving orientations of component requirements towards suppliers also with a horizon of 18 months.

There could be many root causes from PRS (Product Range Start) to EOL (End Of Life), see appendix 1, that could disturb the process to deliver the products on time. One of the root causes Philips is concentrating on is the availability of critical components. The idea is to improve this availability by giving orientations to component suppliers in an earlier stage. Doing so, suppliers can use this early information for creating sufficient capacity to supply the required volumes of components to Philips assembly centers.

This requires to have new types available for sales planning 18 months before commercial release (CR) and also to have for each type a list of key components, the planning bill of material. 18 months before CR is the beginning of the reference architecture phase. So the question is: *Could architects give a forecast of key components in the most early phase?*

2.2 Problem definition

In the past many processes in the PCP could be handled intuitively. Now processes have become much more complex. One of the steps to realize a more formal explicit and measurable PCP, concerns the elicitation of the architecture creation process. With this step in mind the following initial research questions have been defined for this graduation project. In addition, Philips CE wishes to increase the efficiency of the formalized processes by automating targeted areas.

The problem is that Philips CE thinks that it is running behind in managing reference architecture creation processes and therefore insight in the reference architecture process is needed in order to handle the external change and to give proper answers to the questions derived from the current PDM and Filocity projects.

Research questions

1. *What is a more detailed process description of the reference architecture creation made in the different parts of Philips CE and what process activities could be executed with support of the Product Data Management system, without extra effort of the Architects?*

2. *What are the most adequate moments in time during the reference architecture creation process to include, data about key components, the physical view, the functional view and the requirements view of the reference architecture in the Product Data Management system?*

2.3 Goal of the graduation project

The goal of this graduation project is to get better insight in the process of reference architecture creation. With this insight Philips wants:

- to predict key components that are needed in an earlier phase.
- to include information about the reference architecture in the PDM system at an adequate moment
- to get insight how to control the diversity of products with reference architectures.

2.4 Assignment

Philips CE wants to create a process description, (practical guideline, project life cycle models and common terminology) of reference architecture creation that on one hand standardizes this process in Philips CE and on the other hand shows the most adequate moments in time during the reference architecture creation when documentation of key components, physical view, functional view and requirements view of the reference architecture could be included in the product data management system.

Giving the timeframe and opportunities feasible, the assignment is:

Create a process description (i.e. practical guideline, project life cycle models and common terminology) of the reference architecture creation that standardizes this process within Philips CE.

2.5 Scope

The assignment will focus on the architecture and standard design phase (A&SD) of the PCP SPEED model. The output of this assignment intended to be applicable for all BCU's of Philips CE. However given the timeframe, the case studies are limited to Jaguar at BCU TV (Up market, Bruges), the DVD+RW project at BCU Audio and the T5 project at Lighting.

2.6 Research Approach

In this paragraph the research approach is given. Given the assignment it's necessary to get insight in theoretical models. The starting point will be the model that's already prescribed by the PCP-office, see appendix 1. Models for reference architecture creation process can be found in literature and other sources. For deeper insight and feasibility of the reference model, case studies should be done within Philips. Therefore has been chosen for the approach showed in Figure 2.2.

Following Figure 2.2, the starting point is the reference architecture creation process of the PCP office. This process model will be extended with more detailed process steps discussed in several models out of the literature (Theory). Very extensive, because we want to include activities as much as possible. This together forms an improved model, the reference model 1. An analysis about the theoretical models is given at the end of chapter 3.

To validate the reference model 1, the next step will be the analysis of three case studies within Philips. Feedback will be delivered from the Jaguar project, the DVD+RW project and the TL5 project at Lighting. As explained in chapter 4. This feedback will improve and upgrade the reference model 1, into the reference model 2. In the end of each case, an analysis is given. In chapter 5 the Use and Implementation of the model is described and in chapter 6, conclusions are made and recommendations are done.

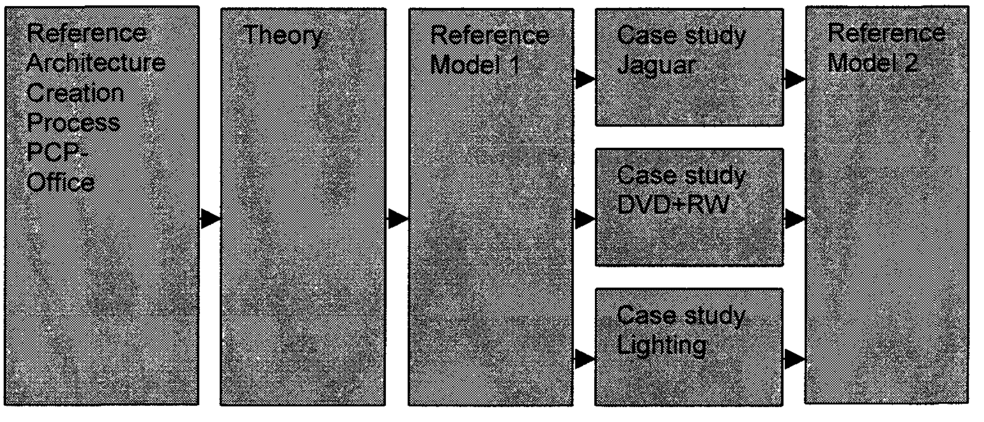

Figure 2.2: conceptual model of research approach

2.6.1 Theory

The following approach for literature research is made.

Library information sources

Information is coming from sources out of the library of the Faculty of Technology Management of Eindhoven, University of Technology. In the ABI-inform source articles were searched with the following key words: product development, product platform, product family, development process, innovation management, Architecture creation, architecture, product creation and others. A few useful articles were found.

PCP-office

PCP-office has a series of documents, which describe the product creation process. The documents related to architecture and standard design have been studied.

Books

The supervisors recommended some books. Research in the library delivered some books. Suggestions came from the internet, some sources in Philips Natlab and the faculty of mathematics in Eindhoven. Only books younger than 10 years were taken, because information in older books would be out of date. Preference was given to books that were written most recently.

Internet and intranet
Looking in the internet and intranet some interesting links were discovered. They are mentioned in the literature list.
Professional Organizations
The IEEE (Eye-triple-E) is a non-profit, technical professional association. The full name is the Institute of Electrical and Electronics Engineers, Inc. Here some papers and standards in relation to the architecture process were discovered.
Interviews
There are people within Philips CE (previous architects), Philips Natlab (Gaudi project) and TUE/SAI. Those people gave me some more insight and ideas for new sources.
Journals
The TUE coach suggested some journals, like Journal of engineering design and Design studies.

2.6.2 Case Studies
For the case studies the following approach is made.
PCP-office
PCP-office has certain knowledge of the different cases. Interviews are held and documentation is red about the different cases.
Interviews
Interviews are held with people involved in the different cases.
Intranet
Certain insights in the cases were found on the intranet.

3. Theory

In this chapter literature about architecting and its life cycle models is presented. Goals for this study will be set in the first paragraph, the approach to reach these goals is described in the second paragraph and the results of the study are summarized in the third and fourth. At the end of this chapter an analysis is made of the literature and the initial model. Deliverable of this chapter is the reference model I that is presented in the Appendix.

3.1 Goal

The first goal is to get insight into the context and deliverables of architecting, like documents and drawings of different views of the architecture in each step of the process.

The second goal of this literature study is to find out what process steps are described in literature for the architecture creation phase of a product platform.

3.2 The context, relevant issues and deliverables of architecting.

In this paragraph the context, relevant issues and deliverables of architecting is explained to get some insight in the complexity of architecting.

3.2.1 What is architecting? (Eberhardt, Rechtin and Maier, 1996)

According to the art of system architecting [5], architecting is creating and building structures, i.e., “structuring”. It strives for fit, balance, and compromise among the tensions of client’s needs and resources, technology, and multiple stakeholder interest.
Architecting is both an art and a science – synthesis and analysis, induction and deduction, and conceptualization and certification – using guidelines from its art and methods from its science.
As a process, it is distinguished from engineering in its greater use of heuristic reasoning, lesser use of analytics, closer ties to the client, and particular concern with certification of readiness for use.
The foundations of architecting are a systems approach, a purpose orientation, a modeling methodology, ultra quality, certification, and insight. To avoid perceptions of conflict of interest, architects must avoid value judgments, avoid perceived conflicts of interest and keep an arms length relationship with project management.
An architect should be skilled as an engineer and creative as an artist or the work will be incomplete. Gaining the necessary skills and insights depends heavily on lessons learned by others, a task of education to research and teach. The role of architecting in the systems acquisition process depends upon the phase of that process. It is strong during conceptualization and certification, but never absent. Omitting it at any point, as with any part of the acquisition process, leads to predictable errors of omission at that point to those connected with it [5].

3.2.2 Goal of architecting (Martin, 1997)

Architecture can be defined as: The highest-level concept of a system in its environment. The scope of this environment could be different. Later on the hierarchy of architectural scopes is explained. An architectural description is a model (document, drawing, product or other artifact). An architectural description conveys a set of views each of which depicts the system by describing domain concerns. The goal of architecting is to structure the system as good as possible, The goal of architecture description is to communicate and record this structure.

3.2.3 Framework of Architecture description (Ares, 2000)

To get insight in what context architectures are placed, a framework of Ares is showed in figure 3.1.
Ares: architectural reasoning for embedded systems. Ares is a project carried out by six partners, funded by the European commission. The project was concerned with the application of software architecture research results to practical problems faced by the industrial partners. In the Ares project the framework described in the figure 3.1 is used.

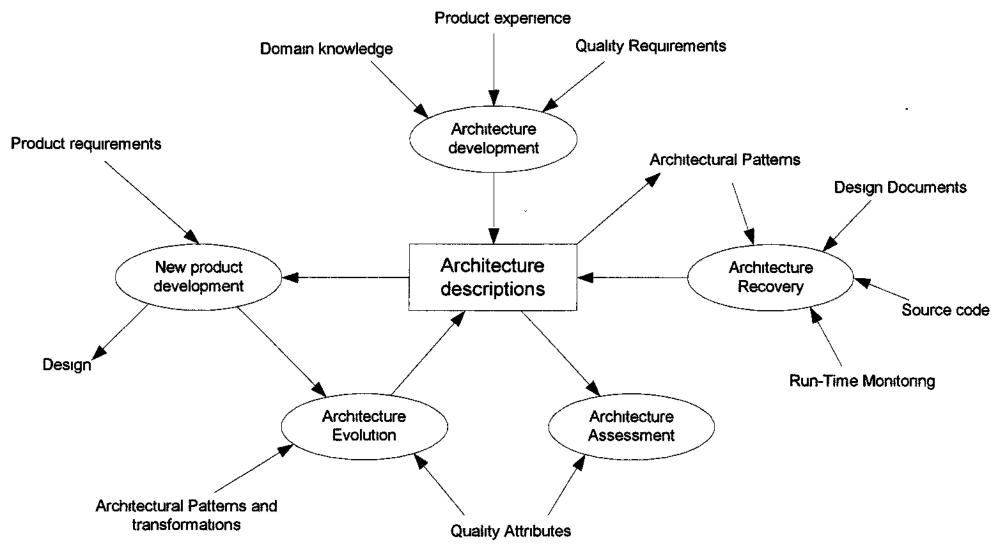

Figure 3 1 Framework of processes and assets Associated with Architecture-centered Software development

The Ares framework shows by what factors the architecture description is influenced. The scope of the literature study and assignment is architecture development with on one hand its inputs (quality requirements product experiences and domain knowledge), and on the other hand its outputs (the architecture description). [7]

3.2.4 Hierarchy of architectural scopes: (Yazayeri, Ran and van der Linden, 2000)
To find out what kind of abstraction level or hierarchical scope is suitable for the architecture the following scopes are studied:
Reference architecture is the collection of concepts and patterns of structure and texture that allow the systems conforming to one architecture to inter-operate and to be managed with the same tools and procedures. Probably the most famous example of reference architecture is the OSI-layered model of communicating systems. Because the emphasis is on interoperation, reference architectures focus primarily in the runtime component domain. OSI: In the early 1980s, the International Organization for Standardization (ISO) recognized the need for a network model that would help vendors create interoperable network implementations. The OSI reference model quickly became the primary architectural model for inter-computer communications. Although other architectural models (mostly proprietary) have been created, most network vendors relate their network products to the OSI reference model when they want to educate users about their products.
Domain specific architecture defines essential domain concepts and functional partitions that enable the development of shared platforms, components, and component frameworks for construction of elements in the specified domain. It is typically concerned with domain-specific infrastructure.
Product family architecture defines the concepts, structure and texture necessary to achieve variation in features of variant products while achieving maximum sharing of parts in the implementation. It is focused on achieving variability.
Evolving-system architecture defines the stable structure and flexibility parameters of the specific system. It defines support for variability in the capacity of the essential features and selection of the secondary (or optional) features provided by the product.
Dynamic-variant architecture defines the structure and texture of elements that enables dynamic configuration of the system. Dynamic-variant architecture was always important to embedded software that had to support multiple hardware configurations. [7]

3.2.5 Different views that can be used to describe and communicate architecture

Perhaps the most important concept associated with architecture documentation is the *view*. Architecture is a complex entity that cannot be described in a simple one-dimensional fashion. The analogy with a building architecture, if not taken too far, proves illuminating. There is no single rendition of a building architecture. Instead, there are room layouts, elevations, electrical diagrams, plumbing diagrams, HVAC system diagrams, traffic patterns, sunlight and passive solar views, security system plans, and many others. Which of these views *is* the architecture? None of them. Which views *convey* the architecture? All of them.

A view, then, represents a set of system elements and their relationships. A view documents a particular aspect of the system's architecture while intentionally suppressing others. Different views will highlight different system elements and/or relationships. It depends for what aspect or stakeholder you need to show the information.
During the literature study a lot of different views were showed. Below a selection of views is showed to give an impression.

4+1 view model (Kruchten, 1995)
- Physical view
- Logical view
- Process view
- Development view

Soni, Nord and Hofmeister (1995)
- Conceptual view
- Module interconnection view
- Execution view
- Code view

Others
- Requirements view
- Functional view
- Behavioral view
- Conceptual view
- Multiple system view
- Performance view
- Service view
- Architectural Views
- Abstract machine model (to identify, separate and represent relevant properties and capabilities of the machine)
- Integration and combination of software view
- Darwin view
- Deployment view
- Document view
- Automatically recovered view
- Manually recovered view
- Semi automatically recovered view
- SDL view (Software description language)
- PCB view (printed circuit board)
- Etc.

3.2.6 4+1 approach to architecture (Kruchten, 1995)

Several authors have prescribed specific views that practitioners should employ to document their software architectures. In particular, Philippe Kruchten of the Rational Corporation wrote a very influential paper describing four main views of software architecture that can be used to great advantage in system-building, plus a distinguished fifth view that ties the other four together the so-called "4+1" approach to architecture:

- The *logical view* primarily supports behavioral requirements, the services that the system should provide to end users. Designers decompose the system into a set of key abstractions taken mainly from the problem domain. These abstractions are objects or object classes that exploit the principles of abstraction, encapsulation, and inheritance. In addition to aiding functional analysis, decomposition identifies mechanisms and design elements that are common across the system.

- The *process view* addresses concurrency and distribution, system integrity, and fault tolerance. It also specifies which thread of control executes each operation of each class identified in the logical view. The process view can be seen as a set of independently executing logical networks of communicating programs ("processes") that are distributed across a set of hardware resources, which in turn are connected by a bus, local area network (LAN), or wide area network (WAN).

- The *development view* focuses on the organization of the modules in the software development environment. The units of this view are small chunks of software, usually program libraries or subsystems. The development view supports allocating requirements and work to teams. It also supports cost evaluation, planning, monitoring project progress, and reasoning about software reuse, portability, and security.

- The *physical view* presents the system's requirements such as availability, reliability (fault-tolerance), performance (throughput), and scalability. This view maps the various elements identified in the logical, process, and development views, networks, processes, tasks, and objects onto the processing nodes.

Finally, Kruchten prescribes using a small subset of important scenarios, instances of use cases to show that the elements of the four views work together seamlessly. This is the "plus one" view, redundant with the others but serving a distinct purpose.

While those are indeed useful views in general, they are not useful for every system, and do not constitute a closed set. The point is that a view is a powerful mechanism for separating concerns and communicating the architecture to a variety of stakeholders. This leads to a fundamental principle of software architecture documentation:

Documenting an architecture is a matter of documenting the relevant views and their relationships, and adding documentation that applies to more than one view.

3.2.7 Philips research uses a 5-view model to define the product family (Philips Gaudy, 1999)

Philips Research is describing some views in their Gaudy project book. With this Gaudy project Philips research hopes to get frequent feedback from others. An open creation process pursues frequent feedback. Philips Research hopes to learn about the processes and organization and later on give a good contribution to the different business creation units of Philips. In this book the following views are discussed.
The customer view represents key concepts in the world of the customer (which is not necessarily the end user). This view is expressed in terms of customer value drivers, customer business models, and the market (including complementors, competitors, the customer customers).
The application view represents application concepts realizing the customer drivers. Identifying stakeholders, by generating scenarios, and by developing a domain model and use cases, typically develops the application view. Important other activities include determining the scope of the family, and estimating the amount of variation within the family.
The functional view describes the commercial decomposition, price / performance ranges, and dimensioning. The functional view is constructed by identifying functions and features, and by evaluating the resulting products in terms of various qualities. As part of the functional view, commercial requirement specifications are written. These CRS state product requirements in terms the application domain model.
The conceptual view describes the family in terms of platform, products, components, and models for various other aspects. In identifying platform, components, and support for diversity, the application view and functional view are important.
The realization view describes the key technical choices to realize the platform, components, and products.

3.3 The different process models for architecting

In the previous paragraph, the context, relevant issues and deliverables of architecting have been explained to get more insight in the context of the problem. In this paragraph we will discuss process-steps and life cycle models of the architecting creation phase. There are models for single products and more general models for product families. Some models are made for software use but could also be used for hardware and system architectures. In fact all models could be practical for further research.

3.3.1 The Waterfall model: (Royce, 1970).

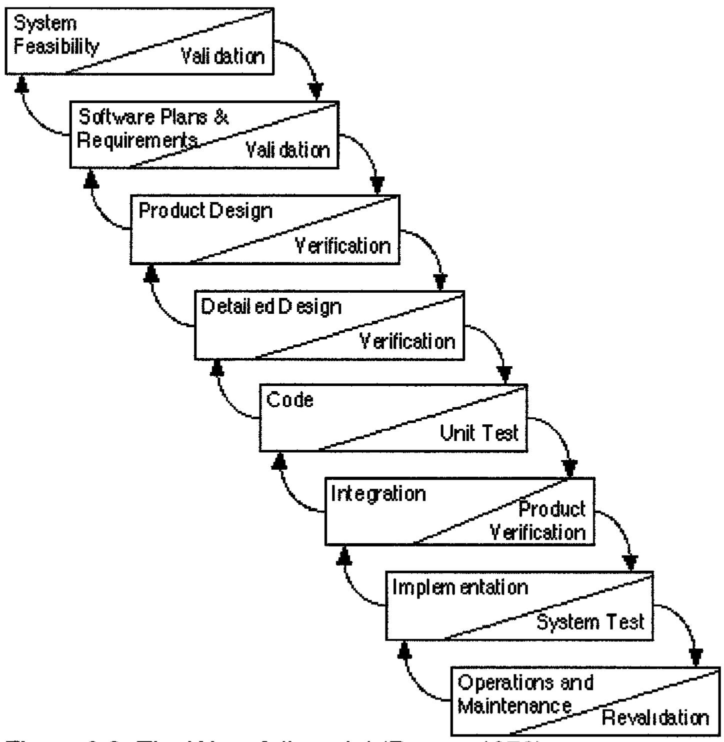

Figure 3.2: The Waterfall model (Royce, 1970)

1. *Feasibility:* Defining a preferred concept for the software product, and determining its life-cycle feasibility and superiority to alternative concepts.
2. *Requirements:* A complete, verified specification of the required functions, interfaces, and performance for the software product.
3. *Product Design:* A complete verified specification of the overall hardware-software architecture, control structure, and data structure for the product, along with such other necessary components as draft user's manuals and test plans.
4. *Detailed Design:* A complete verified specification of the control structure, data structure, interface relations, sizing, key algorithms, and assumptions of each program component.
5. *Coding:* A complete, verified set of program components.
6. *Integration:* A properly function software product composed of the software components.
7. *Implementation:* A fully functioning operational hardware-software system, including such objectives as program and data conversion, installation, and training.
8. *Maintenance:* A fully functioning update of the hardware-software system repeated for each update.
9. *Phase out:* A clean transition of the functions performed by the product to its successors.

3.3.2 The Win-Win Spiral Process (Barry Boehm, 1998)

The Win-Win Spiral Process explicitly emphasizes continuous collaborative involvement of a software product's stakeholders in its early definition and development stages.

The two main distinguishing features of the Win-Win Spiral Process are:
1) It provides an explicit set of goals (identification and reconciliation of stakeholder win conditions) for collaborative software definition and development, and

2) It embeds collaboration activities explicitly within a robust life-cycle process model, the Spiral Model.

The resulting process uses the Theory W win-win approach to converge on a system's next-level objectives, constraints, and alternatives. The Win-Win Spiral Process uses the following two steps to accomplish this:
1) Identifying the system's stakeholders and their win conditions and
2) reconciling win conditions through negotiation to arrive at a mutually satisfactory set of objectives, constraints, and alternatives for the next level.

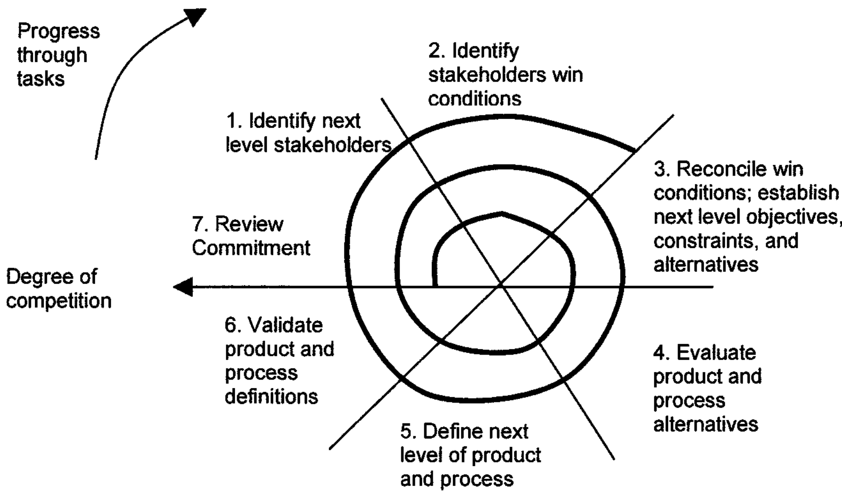

Figure 3.3: The Win-Win Spiral Process (Barry Boehm, 1998)

The 7 Steps of the WinWin Spiral Model:
Step 1: Identify next-level Stakeholders.
Step 2: Identify Stakeholders win conditions
Step 3: Reconcile win conditions. Establish next level objectives, constraints, alternatives.
Step 4: Evaluate Product and Process Alternatives. Resolve Risks.
Step 5: Define Next Level of Product and Process, Including Partitions
Step 6: Validate Product and Process Definitions
Step 7: Review, commitment

In conclusion, the Win-Win Spiral Process Model is a model of a process based on Theory W, which is a management theory and approach "based on making winners of all of the system's key stakeholders as a necessary and sufficient condition for project success.

The original spiral model uses a cyclic approach to develop increasingly detailed elaboration's of a system's definition, culminating in incremental releases of the system's operational capability.

3.3.3 The RUP (Rational Unified Process) (Rational University (RU) and partners, 2000)

The Rational Unified Process is a Software Engineering Process developed and maintained by Rational® Software. [www.rational.com] It provides a disciplined approach to assigning tasks and responsibilities within a development organization. Its goal is to ensure the production of high-quality software that meets the needs of its end-users, within a predictable schedule and budget.

In the Rational Unified Process, the development lifecycle is presented and discussed from two perspectives: the management perspective and the development perspective. see figure 3.4.

From a management perspective, it goes through four lifecycle phases to develop a system, or a new generation of a system. From the development perspective, it develops iteratively versions of the system that are incrementally more and more complete. The activities it performs during an iteration has in the Rational Unified Process been grouped into a set of core workflows. Each core workflow focuses on describing some aspect of the system, resulting in a model of the system, or a set of documents.

		Phases			
	Core Process Workflows	Inception	Elaboration	Construction	Transition
Disciplines	Business Modeling	xxxxxxxxx	xxxxxxxxxxx		
Disciplines	Requirements	xxxxx	xxxxx x	x x	x
Disciplines	Analysis & Design	x	xxxxxxxxxxxxx	xx	
Disciplines	Implementation		xxxxxxx	xxxxxxxxxxxx	x
Disciplines	Test	xx x	x x x	x x x	xx xx
Disciplines	Deployment			xx	xxxxxxxx
	Core Supporting Workflows				
	Configuration & Change Mgt.	x	x	x xxxxxx	xxxxxxxxxxx
	Project Management	xxxxxx	xxxxxx	xx xx xx	xxx
	Environment	xxxxxxxxx			
		Prelimi It	It. 1 It.2	It. n It n+1	It.M-1 It M
		Iterations			

Figure 3.4: Rational unified process, (Rational University (RU) and partners, 2000)

In the Rational unified process, five core process workflows are introduced, see figure 3.4 & 3.5. These are:

- Business modeling – the purpose is to assess the organization in which the system will be used, to better understand the needs and problems that is to be solved by the system. The result is a business use-case model and a business object model. This workflow can be considered optional, and only adds value if the organization has some complexity that needs to be explored.
- Requirements - with the purpose to capture and evaluate the requirements, placing usability in focus. This results in a use-case model, with actors representing external units communicating with the system, and use cases representing transaction sequences, yielding measurable results of value to the actors.
- Analysis and Design – with the purpose to investigate the intended implementation environment and the effect it will have on the construction of the system. This results in an object model, including use-case realizations that show how the objects communicate to perform the flow of the use cases. This might include interface definitions for objects and subsystems, specifying their responsibilities in terms of provided operations. This object model is also adapted to the implementation environment in terms of implementation language, distribution etc.
- Implementation – with the purpose to implement the system in the prescribed implementation environment. This results in source code, executables, and files.
- Test – with the purpose to ensure that the system is the one intended, and that there are no errors in the implementation. This results in a certified system that is ready for delivery.

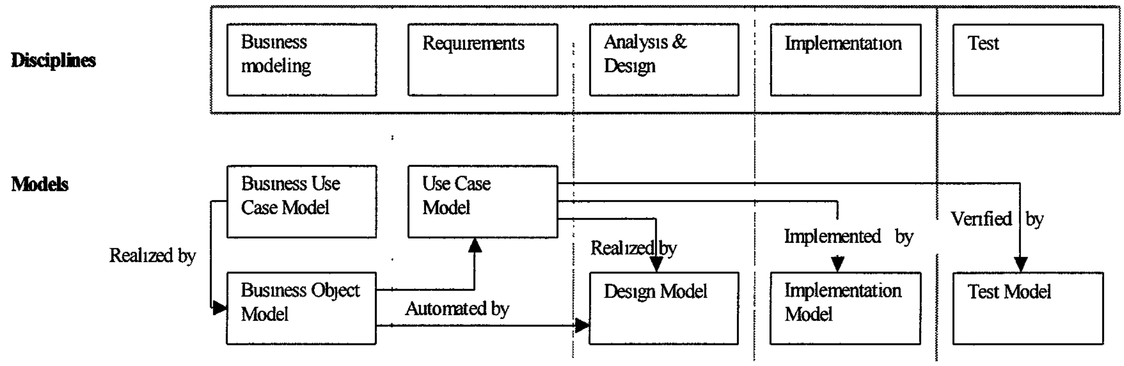

Figure 3.5 . Each core process workflow is associated with a particular set of models, (Rational University (RU) and partners, 2000)

3.3.4 Software reuse, Architecture, process and organization for business success; (Ivar Jacobson, Martin Griss, Patrik Jonsson, 1997)

In this book 5 steps are described for the development of an architecture for an application family. Despite this book is software oriented, it is useful for hardware architecture also.

The following steps are described:

1. **Capturing requirements that have an impact on the architecture**. Find out who the customers and the end users are and the needs and expectations they have. Make a first approximation of a product plan and use it to decide which parts to focus on. Perform the first iteration of requirements capture and analysis to find actors and use cases. Select the most important 5-20% of the use cases and describe them. Do some analysis of use case variability.
2. **Performing robustness analysis**. Use the selected use cases to identify candidate application and component systems using a high-level analysis model.
3. **Designing the layered system.** Use the first version of the analysis model to prepare a prototype design model that defines the layered system in terms of application and component systems. Take advantage of legacy systems, third party products, GUI toolkits, utility class libraries, object request brokers, and so on. Use interaction diagrams to divide the use cases among the application and component system in order to precisely define facades and interfaces. Develop a first version of the concurrency model and the deployment model.
4. **Implementing the architecture as a layered system.** Use the product plan to schedule the work on each application and component system. Review the architecture and the plan. Implement the first version of the most important and risk sensitive application and component systems, facades, interfaces, and processes. Integrate legacy systems and Commercial off the shelf (COTS) systems such as object request brokers.
5. **Testing the layered system.** Test each application system both by itself and also part of the layered system as a whole. Testing the layered system is particularly important for application systems that inter-operate. Test against the most notable risks and measure its performance. Capture lessons learned.

Due to the cyclic nature of this process the following steps should be followed too.
Repeat step 1 (requirements capture) for an additional set of use cases. Reassess risks. Perform a more thorough step 2 for the combined use cases, identify how to integrate the new or changed use cases into the robustness analysis. Prepare a design model from the use cases and the analysis model, defining the next version of concurrency model, deployment model, application and component systems, facades, interfaces and integration of COTS and legacy systems. Revise the product plan. Identify the highest-payoff application and component systems and

decide which ones to start developing (possibly none if the architecture still seems too brittle); use this information to focus the next iteration.

3.3.5 System engineering guidebook (James N. Martin, 1997)

In this book general process steps are formulated for the development of systems and products. The requirements and architecture definition sub-process (described in appendix I) provides an orderly and iterative definition of the problem and development of the solution.

- Requirements analysis defines the boundary of the problem and parameters to be satisfied.
- Functional analysis describes the intended behavior of the system in its environment. The 'problem domain' will be defined by these requirements and functions. The 'solution domain' will be defined during the synthesis tasks.
- The 'verification loop' from synthesis to requirements analysis ensures that the solution domain maps correctly to the problem domain.
- System analysis and optimization analyzes the alternative solutions for their effectiveness and narrows the choices for further development.
- The requirements for the final choices will be documented in specifications and interface documents during the requirements and architecture documentation task.

The requirements will be defined for both the system products and the related processes, such as manufacturing, verification, deployment, support, and disposal. A more detailed summary of process steps I described in appendix I.

3.3.6 Capability Maturity Model Integration v:1.1 (SEI, 2002)

The CMMI includes a common set of process areas which form the core of an integrated capability model that integrates process improvement guidance for systems engineering, software engineering, and Integrated Product and Process Development (IPPD). The model provides an integrated approach to reducing the redundancy and complexity resulting from the use of separate, multiple capability maturity models (CMMs). The CMMI products should improve the efficiency of and the return on investment for process improvement. The resulting integrated capability models will be tailorable to an organization's mission and business objectives.

The following blocks of activities are described:

- *Requirements Development*
- *Technical Solution*
- *Product integration*
- *Verification*

3.3.7 Architecture & Standard Design process (Philips CE, Paul de Wit, 1998)

The Architecture and Standard Design process (A&SD) of PCP office is described in more detail in Appendix F. The A&SD sub-process "Reference architecture creation" is the starting point for this research and was the base for reference model 1 and 2.The main elements of the A&SD processes are:

- *Architecture and Standard design planning*: In this process, the future direction of the business with respect to Reference Architecture and product Platforms is defined and documented in a set of roadmaps.
- *Reference architecture creation*: In this process, the requirements of a product family are analyzed. The partitioning into subsystems, a mapping of functionality to subsystems and interfaces between the subsystems are defined and documented. More specific the following parts are described.
    - *Requirements Analyses*
    - *Outline design*
    - *Develop Reference architecture*

- *Standard Design Creation*: This process covers the realization of the subsystems, more specifically the specification, development, testing and documentation of the standard designs.
- *Product Platform Creation*: This process covers the integration and validation of a number of standard designs, from which the members of a product Family can be realized.

3.4 Results of Theory

In this Chapter we wanted answers for the following questions:

- What aspects are related to architecture creation?
- What activities should be done to create a good architecture?
- What activities are recommendable for the reference model I, that is described in the appendix 2?

In paragraph 3.2, the first question is answered. We have seen the context where the architecture is subject to and some insights are shown. Also relevant issues and the deliverables have been discussed.

For the second question, some theoretical models have been described shortly. In literature, theoretical models are mostly developed for single products. I couldn't find many theoretical models specially made for a range of products. In literature most theoretical models are software oriented. Though for using these theoretical models for the reference model 1, the models are general enough.
The goal of the reference model is to use this model as reference and not as recipe. Consequence is that we look for as much possible activities that could have influence on the architecture.
Architecture creation is a very specific part of the product creation process. From this point of view we need only a specific part of the theoretical models. For this reason activities should be placed in the same scope as the initial architecture creation model of PCP, that means the activities between milestone 'Architecture Start' and 'Architecture Defined' (see appendix F).
A different issue is the aggregation level. One could see in the reference model 1, that the aggregation level of the Win Win model, the Waterfall model, the Jacobson model and also the RUP model, is higher than the other theoretical models used. Therefor less suitable for this research to compare and extend the PCP-model.
In the reference model, the documentation phase out of the existing PCP office model is skipped. The final documentation should be the deliverables of the process steps and not process steps itself.

For the third question recommendable activities are described in the reference model 1 that is showed in appendix A. Referring this model, lots of different ways can be walked. The system architect himself is able to delete unnecessary steps. Once again, the reference model is a reference and not a recipe.

4 Case studies

In this chapter three case studies of a reference architecture creation process will be discussed. The goal is

- To get insight in the reference architecture creation process and context of the projects in these three case study's.
- To validate the reference model 1
- To improve the reference model 1 with additional activities.

The next criteria are set for the cases:

- the reference model should be applicable within whole Philips CE.
- Cases should be representative for Philips CE and have compared with each other enough differences.
- Studies should be feasible in the given timeframe and there should be enough base for research.

The following case studies were selected:

- The Jaguar project in Bruges. This is a reference architecture for BCU Up-market TV.
- The DVD+RW project in Eindhoven. This is a reference architecture for BCU Audio.
- The TL5 project in Eindhoven, This is a reference architecture for TL5 lamps at Philips Lighting.

Approach
To get insight in the reference architecture creation process we look at activities and their input and output information, but also to the project and context where the activities are placed. For this reason we structure each case study as follow. First the project is described, than the context and the goal of the architecture. Next, the activities and their input and output documents are described. Finally, an analysis of the case is given, with respect to the reference model 1.

Activities in the projects are clustered in the same way as the reference model is clustered. That means that there are eight main blocks of activities, see reference model 1 in appendix 1. Because of this clustering we could compare the activities of the projects with the activities in the reference model 1. Later the differences are described in what activities are in the projects and are not in the reference model, and visa versa.

4.1 The Jaguar project

4.1.1 Project

Jaguar will be one of the new architectures for up-market television. It will be developed in the global design center in Bruges. This new architecture will be radically different than previous ones. The software / hardware ratio increases. In future, hardware will be more integrated and software shall define the difference in functionality of the TV-sets. Characteristic of this project is that it is for a next generation of products. A goal of this project is to reuse as much as possible. E.g. reuse of architecture parts of earlier architectures or reuse of already proven technologies. When reuse is possible for the reference architecture time-to-market will be shorter and cost will decrease.

The process in Bruges handles a main cycle of 7 years; in here a complete new reference architecture will be developed and after incremental improvements for this reference architecture will be done. The complete new architecture will take 2 years, later small cycles of approximately 1 year take place for the incremental improvements. In these incremental improvements the reference architecture is improved and adapted to new market scenarios. Improvements could be a kind of add-ons of new functionality's. In the first cycle you could speak of radical innovation of the reference architecture. In the yearly cycles you speak of incremental innovation. The complete new reference architecture will be made in 2 cycles. One of 6 months and the other cycle which is more detailed of 18 months.

The Jaguar project started in the beginning of 2002. The architecture is planned to function in 2004 for at least 5-7 years. The architecture should cover 50 to 500 products. Besides the TV-sets for up-market TV, this reference architecture should also cover TV-sets within Projection TV and Flat TV. This will make it more complex.

Partners involved were:
Architects (system, software, hardware, mechanical),
System House,
Philips Research (new technologies),
Strategy, planning and programming department,
Initial purchasers and suppliers,
logistics department (supply chain management),
manufacturing department,

In the beginning about three architects, an initial purchaser and an S&P representative were occupied with the architectural concept of the Jaguar project. With this architectural concept, the guidelines for the project were set and strategic decisions concerning the reference architecture were taken. In a later phase the number of persons involved with the reference architecture and also the product realization phase increase up to 50. More detailed decisions will be made in this stage. Later during the cycles for the incremental innovations, also these 50 persons are involved. The system architect and his team stay responsible. Architects and persons involved in the Jaguar project were and will be dependant of persons throughout whole Philips CE, Suppliers and others to get the necessary information. Communication is vital in this Jaguar project were many persons were and will be involved.

4.1.2 Context

Televisions are already made for decades. The television itself and the color television were major breakthroughs in history. Today the next generation of televisions is produced in all kind of diversities for a whole range of markets. The Jaguar project is a project for up-market TV in BCU TV. TV's characterizes this market with a broad diversity in features and functions. Optimization in all disciplines and areas is one of the key drivers. Manufacturing, Purchasing, Product strategy, Planning and programming, Development and Service are represented in this process as the main disciplines.

In BCU TV the System house department made a planning what kind and with what features the TV's will be necessary in a specific region for the next years. So a full range of TV's is planned for the next 5 years. In the planning and programming phase will be decided what TV's should be made following a specific architecture. Later this architecture should be adapted to this sub range of TV's. This is the assignment where the A&SD phase starts (see Appendix 1). System house makes sure maximal benefit will be generated in a broader scope within Philips. Not only in up-market TV but also in FTV and PTV they could use the same reference architecture or parts of it.

The reason for the Jaguar architecture is the emerging Digital TV (ATSC, DVB etc. and the new flat displays (PDP and LCD). Although the TV as function is still the same and everybody want a flat TV, this is still technology push, but relatively to the DVD+RW project in BCU Audio where new technology is set in the market. DVD+RW project process is more a push process. And so you could say that Jaguar is relatively a pull process.

The characteristic of the production method is that Philips CE and in particular Up-market TV has an assembly driven production method.

4.1.3 Main goal of architecture creation

In the Jaguar project the main goals of the reference architecture are:

- to achieve standardization of the TV-architectures within a defined range of TV-sets.
- create with one reference architecture that cover an as extended as possible range of TV-sets.
- it suits better the range of TV-sets that will be made in the future.

The main goals of the reference architecture creation process are:

- eliminating risks that in a later phase could cause problems in the realization and production phase, prepare the development process to engineer concurrent, save costs and make time-to-market shorter.
- the reference architecture should cover the checklist that is handled at milestone 'Architecture Defined' (AD).

4.1.4 Process

In appendix G, the reference architecture creation process for Jaguar is described.

4.1.4.1 Input

From the programming phase in the BCU itself an assignment was received to adapt or renew the existing architecture. From the System House (Technology know-how generation) further guidelines for the new architecture were received. Other input documents were: Strategic plan, Long term product plan (LTPP), Function / Feature (F/F) roadmap, Purchasing roadmap, results of roadmap alignment with key suppliers, Technology roadmap, Architecture roadmap, Design roadmap, Line chart, Integrated Circuit (IC) user manual, OPS info assignment, Reused layout cells (schemes, constraints, interfaces), product requirements, Human capabilities roadmap, Results of technology know how generation projects, Existing product platforms, feedback from product realization process, Tacit knowledge, Operational requirements: A&SD project/budget overview, production processes, preferred supplier and component list.

4.1.4.2 Activities

Activities of the Jaguar project are here clustered in the same way as the reference model 1 is clustered. That means that there are eight main blocks of activities, see reference model 1 in appendix A. Because of this clustering we could compare the activities of the projects with the activities in the reference model 1. Below the activities are described representative for each cluster.

Requirements development The following activities are done in the Jaguar project: At milestone Architecture start (AS) the assignment is collected and a beginning is made to produce the commercial requirements specifications (CRS). This is a document that asks if several options are possible. Functional Requirements Specification (FRS) The RM-team is responsible for the generation of the SysRS documents. Initial SysRS. Use Case analysis. Discover latent customer needs. Fac /serv. Requirements Environmental requirements.	
Analyze and validate requirements After CRS the answer will be given in the system requirements specification (SysRS) The options here are technically feasible. During the period answers are found for this SysRS, a beginning is made with the final documents. Logical grouping of functionality's. Requirement mapping. Functional model specification. Functional requirement specification. Define architecture concept	
Define scope of architecture The next activities are employed for Jaguar: definition of drivers / scope / feature / function, top level architecture, requirement mapping, control architecture, SW diversity strategy, tooling. Define architecture concept. Architecture options. Requirement mapping. (checkerboard)	
Brainstorm architecture solutions Define functional model specification (FMS) Besides these also a Chassis specification (CHS) is produced and a hardware-software interface (HSI). Architecture options and architecture concept are defined	
Make detailed design The different development disciplines generate their derived documentation (FRS, CHS). The FMS that should be the input for the CHS is also made in parallel with the other documents	
Synthesize system element alternatives Function mapping. Define Work Breakdown Structure-first product platform (platform validation preparation). Define user interface. Define modules, layout cells interface, space, temperature, EMC, Power balance. Key components overview and status. Digital connectivity (USB, !394, 802.,PCMCIA, S-ATA, HDD). Define chassis specification, set architecture brackets, shielding, tooling, platform diversity	
System analysis and optimization activities The main characteristic of the process is that you try to imagine possible faults as much as possible, and than you try avoid this possible risk. There are a lot of risks analyzed in history, so there are lots of detailed lessons learned.	
Selection of platform Milestone Architecture Selected.	

4.1.4.3 Output

According to an agenda for the milestone meeting of the first stage in the jaguar process, the process has the following output documents:

Drivers, Market, Scope, Feature Function
Concept saving, Business Justification, NPV
Modules, layout cells, interface, space, temperature, EMC, Power balance
Top Level architecture, requirement mapping, control architecture, SW diversity strategy, tooling
Set architecture (PTV, CRT, FTV), Brackets, shielding, tooling, platform diversity
Digital connectivity (USB, ! 394, 802., PCMCIA, S-ATA, HDD)
PTV (spec coverage), interfaces (HW, SW, Mech.), contract book
FTV Platform status, (Spec coverage), interfaces (HW, SW, Mech.), contract book
Requirements management (SysRS, FMS, CHS, FRS)
Quality plan, risk assessment, Field Call Rate (FCR)
Platform diversity mapping
Environmental requirements and status

Key component overview and status
Patent position/ infringement
intellectual property right (IPR) status
Industrial strategy and industrial costs IC2, IC4
Service and repair strategy
Work breakdown structure- first product platform (platform validation preparation)

4.1.5 Results
As result of this study we could say that Jaguar is a more developed and detailed process than the DVD+RW and TL-5 processes. Therefor many things could be learned of this case study. In relation to theory we have seen that this case study is much more specific in its terminology. We will now describe Jaguar in two ways: What is in the reference model and is not in the case study process; What is in the case study process and is not in the reference model. Next some other remarks are described, related to this analysis.

What is in the reference model and is not in the case study process
The following activities are in the reference model but not in the case study: develop standard design requirements; allocate standard design requirements; define measures of effectiveness; analyze requirements to achieve balance; develop life cycle techniques and procedures; define operations and support concept and define functional interfaces.

Arguments for the absence of these activities of the Jaguar project, could be the phase of the project at the time the interviews were taken. The interviews took place in the first cycle of the reference architecture creation process. During this first cycle only guidelines and main problems to be solved are identified. However this is just an assumption. It is difficult to find arguments for the identified differences because the Jaguar architecture creation process is in it's definition phase and persons involved did not have a clear view yet about the content and process to be realized.

What is in the case study process and is not in the reference model
The following activities are in the case study model, but not in the reference model 1: strategy and planning activities; hardware / software distinction; service and repair strategy; define user interfaces; concept saving, business justification; NPV; definition of industrial strategy and industrial costs.

Argument for this difference is that in practical situations activities are more specific than general valid activities, and therefor not mentioned in the reference model.

Other remarks
→To create an architecture with an as extended as possible range of TV-sets, trade off calculations should be made to come to an optimal size of diversity.
→ In practice sometimes checklists seems of better use than a detailed process description. In practice both process descriptions as well as output checklists are necessary. Process descriptions will help the project team in carrying out their tasks while output checklist are valuable to evaluate if the intended output (result) has been achieved.
→The activities selected by system architects can be dependant on what components you make yourself and what components are outsource-ed. Components that were outsourced are less easy to adapt to change than components that you make yourself.
→The model developed in this case, and described in appendix G, is a good starting point for further research. It could have benefits if besides a reference model also a specific model will be developed. It will deliver feedback and discussions. Therefor it would be wise to further develop this model.

4.2 DVD+RW

4.2.1 Project

In this project the reference architecture for the world's first DVD+RW Consumer Recorder is created. The product is fully DVD compatible and has a DV Camcorder connection. First several technologies were evaluated. Once was, the so-called "blue-ray" technology. This was found too difficult to bring to at the market given the status of the technology and the timing constraint. Finally the option DVD+RW was used. This evaluation period took ca. 3 months. The DVD+RW project was a "first of a kind" project. Project members only have experiences from other previous products like DVD. In this early phase still no roadmaps exists. Because the market is not familiar with the product, it is difficult to know what the market wants. Scouting has to be done to know what functionality suppliers could offer. Market research was done in order to learn what requirements are necessary. This could take 4 to 8 months.

Philips started the DVD+RW project since 1999. Several DVD-recorders were introduced since September 2001. The creation and implementation of the reference architecture took three years. It started with 3 architects and grew to 10 architects during the 3 years. As much as possible reuse of existing functions was done. Architects came from different fields of knowledge with much experience. During this 3 year architects were busy with lots of trade-off's: Where should Philips be in the market? What supplier has to be chosen? What's important: time-to-market or good features? What's the development strategy? What are fallbacks plans?

A team of architects including a system architect, a hardware architect and 6 software architects developed the design. From Hardware and software expertise the DVD expertise, especially of the streaming behavior was built up during earlier projects. Historic integration know-how was vital.

The project was executed in strong partnership with PDSL. PRLE (research) invented a basic video-encoding algorithm, which was optimized in close operation with PDSL and Semiconductors Hamburg. In the demonstrator or feasibility phase, the VDR project developed a single pass video-encoder with an embedded processor.
In parallel the IEEE1394 project created an input for camcorder connection, allowing to download DV footage onto an optical disc.

The following Partners were involved:

PCMS Hasselt	Pilot and mass production preparation.
Philips Vienna	Development of the VCR analogue board with its SW.
POS	Development of Basic Engine.
PSC Bangalore	DVD playback SW.
IC Lab in SFJ	Layout and simulation of the VSM IC.
PS,	Development of Empire and Empress IC's.
Philips Design,	Styling.
DVD+RW department	provided overall project and software project management at PDSL premises.
PDSL	provided hardware, encoding SW, system know how and integration projects and its management.

About infrastructure for product development.
Outstanding facilities were directly available without the need of additional investments (computers, networks, video content etc.). PDSL originally developed the 'Test Generator' (indispensable for the test phases). The PDSL team consisted of 90 people (total team size = 150). Lead time of definition phase: 22 weeks. Execution phase: 96 weeks. The project was completed exactly on time.

In the second-generation products 2003, after the first of a kind product of 2001, some major features where added. In the third generation the products will become more mature and than you know better what customers want. Philips DVD+RW is able to plan the process better in this third generation. In this third generation a whole range of products becomes possible.

4.2.2 Context
In the bigger context DVD+RW is a successor of a series of technologies. (CD, CD-R, CD-RW, DVD, DVD+RW) In a smaller context you could speak of a radical innovation. This new technology makes it possible to develop a whole range of new products. For this reason the DVD+RW market is a young new market. Nonetheless Philips could use earlier experiences.

The recent range of products covers 2 main segments: The low-end market (70% of the products sold) and the high-end market (30% of the products sold). World wide three formats exist on the market. DVD+RW (Philips et al), DVD-RW (Pioneer et al) and DVD-RAM (Matsushita et al).
For DVD+RW Philips Optical Storage, Business Unit of Philips Components produces the drives. Philips CE sells the products to the CE market. And Philips components sell PC drives business-to-business to the computer industry. Both markets generate royalty income for Philips.

Initially in the first years the drives can be used in both markets. Later the drives of the computer business and consumer electronics business will diverge. This because goals are different. Computer business is interested in high speed for data processing: the so-called X-game. Consumer electronics business is interested in the speed to play a movie only, so this business is more focused on cost down. However still a lot of key components could be the same.

The advantage of the Philips format is that it developed to be compatible with the PC needs as well. DVD-RAM for example is not compatible with PC needs and for this reason it did not take off in the PC market.

Business factors in development are: Price erosion and number of functionality's and features. Important is how are you doing business in the highest market segment, while maintaining a good market share in the low-end market? Who is the first one with new features?

The characteristic of the production method is that Philips CE and in particular DVD+RW has an assembly driven production method.

Feasibility study for the DVD+RW project for the 2nd generation took a couple of weeks. Architecture outline took ca. 2 months. Each two weeks there are project reviews. At the milestones go/no go decisions are made. Management reviews are held and traffic light reports are written. Also PCP audits are done.

4.2.3 Main goal of architecture creation
The main goal of architecture creation for this project is to create a product architecture so that time-to-market could be fast.

4.2.4 Process
DVD+RW is a first of a kind project. The process for DVD+RW is less structured than the Jaguar or TL-5 as one can see in paragraph 4.3. This is because the nature of the process is different. The main goal is to be as fast as possible at the market. A robust architecture is not as important as for a third generation of products when lots of products are dependent on it.

Planning of the process is done by experience. You know what the deliverables are: 6 architecture description documents and 3 requirements documents. So estimations could be done how much time is necessary for each document. There is always a trade-off done in how much time is necessary to get an ideal architecture and how much time you could spent will it be profitable. Initially when the first of a kind process of DVD+RW starts time-to-market is most important, than featuring, than bill of material is important. In the end of the process especially in the second and third generation products, these seems to turn around.

4.2.4.1 Input

Inputs of the process are:

Commercial requirements specifications (CRS),
Information out of the scouting activities,
Information from the product planner,
Information out of benchmark studies.

4.2.4.2 Activities

Activities in the DVD+RW project are clustered in the same way as the reference model 1 is clustered. That means that there are eight main blocks of activities, see reference model 1 in appendix 1. Because of this clustering we could compare the activities of the projects with the activities in the reference model 1. Below the activities are described representative for each cluster.

Requirements development Besides functional also non-functional requirements are important. (e.g. the performance requirements are underexposed) Other aspects important in the requirements specification are copy protection and political issues. Standard designs specifications are almost no issue because it's a first of a kind product.
Analyze and validate requirements After the architecture roadmap (and related Function Feature roadmaps) is finished each 6 months reviews are done and the horizon of roadmaps are extended.
Define scope of architecture
Brainstorm architecture solutions
Make detailed design In each situation the depth of the activity will be different. It depends on the architect and its team if they think the information is robust enough. Also. PDSL, Semiconductors and Hasselt used different scopes.
Synthesize system element alternatives In the initial phase of the process: It's important to find out what should be key components and who will supply them. (Key components are also software components.) Often project members themselves will make IC's. The usage of software stacks is important.
System analysis and optimization activities In the beginning risk workshops will be organized with a lot of architects to collect all expected risks and make a priority list. The 10 biggest risks are managed in the project.
Selection of platform

4.2.4.3 Output

The next modules are in the architecture:

DVD video decoder
Video encoder
Audio encoder
Digital Video input
Drive
Audio/Video module: Tuner/Timer (VCR)

4.2.5 Results

As first of a kind architecture we have seen that DVD+RW is less detailed than the Jaguar or TL-5 project. This project uses the PCP-office model as reference and has no specific or developed structure to walkthrough the reference architecture process. Below we will describe the differences of this DVD+RW study and the reference model 1 in two ways: What is in the reference model and is not in the case study process; What is in the case study process and is not in the reference model. Next some other remarks are described, related to this analysis.

What is in the reference model and is not in the case study process

Though, all activities of the reference model are done in this case study, activities are done in a less structural or detailed way than in the case of Jaguar. The effort here lies in the goal to reach a fast time-to-market.

What is in the case study process and is not in the reference model

DVD+RW organization adheres in principle to the PCP model. Where needed deviations from the PCP model are agreed upon and listed in the project plan. The following deviations were noticed:
The analysis of the risks in advance is not mentioned clear in the reference model.
The reference model doesn't take planning activities into account.

Argument for these differences could be the unstructured nature of this first of a kind process of this project. The goal was to finish the prioritized list. Activities that supported this goal were done while others weren't.

Other remarks

In this paragraph remarks are made that are useful to get further insight as we wanted following the research questions described in chapter 2.

According to persons involved in the DVD-project the list of activities of the reference model 1 looks complete. The reference model 1 could be nicely used as a checklist. Though the activities and the list of priorities that should be done for the DVD+RW project were in the heads of the system architects. It's difficult to give any order in the list of activities cause most activities should be done concurrent.

Breakthrough development is different from incremental development. For example market predictions in breakthrough development are less secure and are subject to variations and change. There are architects, who are specialized in the breakthrough or "first of a kind" product architecture creation process. These architects know a lot of technology issues and risks. There are also architects who are better specialized in incremental or "the second or third generation" of the architecture creation process. Those last architects could better predict what the market wants, and are more cost down driven.

There is a trend in Philips CE that Philips CE does fewer activities herself. Because of the farm out of activities Philips CE gets more and more dependant of its suppliers.

Short-term innovations are dependent on the progress made by the suppliers: POS and Semiconductors who could add different features and technologies. This is most of the time complex because it's all new. For the long-term (5 years and longer) a framework is made that stays practically the same. Each block within the frame will undergo a major redesign to lower the cost and add functionality.

To be the first in the market often separated hardware blocks are added to the core system blocks. Later on these separate block functionality's will be integrated in the core system blocks and than with additional software you could make the difference in features and functions.

4.3 Philips Product Division Lighting (T5)

4.3.1 Project

A representative project in this division is the recent architecture creation of the production machine of T5 lamps. The goal of this project is to stay ahead as market leader in the TL market. This project took place in BG Lamps. T5 is a new type of fluorescent lighting system. It's based on a new slim fluorescent lamp that's just 16mm in diameter instead of the conventional 26mm (T8) or 38mm (T12) lamps. T5 lamps are designed for exclusive use with High Frequency control gear so they always illuminate in an instant without any flicker. Also, even though the lamp is 40% smaller than conventional T8 lamps, its superior performance means more lumens per watt.

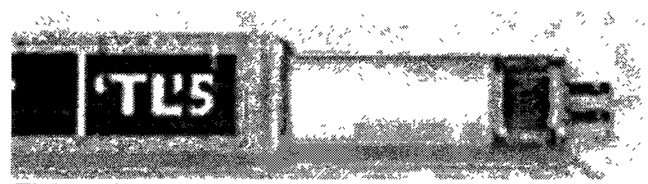

Figure 4.1 Photo of a TL5 product.

The market trend of the products of TL lamps are rather simple. In the 1980's the diameter of tubes were 1 inch, in the 1990's the diameter was 8/12 inch and nowadays the TL-lamps are 5/12 inch in diameter. The trend is miniaturization

The product technology is rather stable. It exists of a tube of glass with fluorescing powder in it. There are two electrodes at both ends that cause a low-pressure gas discharge in between.

The production technology is a more complex issue. For first of kind products no big costs are made. First has to be proved the product is right for the market. For T5, in the early part of its lifecycle, the vertical production technology was used: the so-called VTL platform. This is a good method for velocities of 500 lamps per hour. When the product's sales volume increases the Horizontal production method is needed to reach velocities of 6000 products per hour. This is based on the so-called HTL platform.

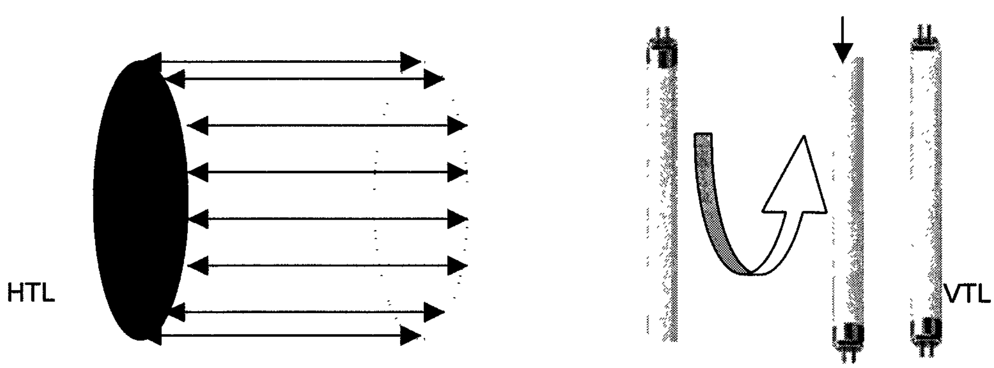

Figure 4.2 A representation of the HTL and VTL production method.

In the VTL platform, the first step is to melt a head on the tube. Then the tube is turned upside down. Next step is to fill the tube with fluorescent powder to get the coating on the tube. In the end the other head is melted on.
In the HTL platform the tubes don't have to switch. Production is done with a carrousel. Both heads are melted in the same time. With this method the production velocity is much faster.
The added value of Philips in this business is using the knowledge of process technology. Lots of profit could be made by higher velocities and efficiency of the production process. The new

architecture of the production machine should cover the diameter-range from 4/12 to 8/12 inch lamps.

T5 history.
The idea for T5 was born around 1995. The development of the product took and preparation of production took around 2 years. In 1997, production was started on a VTL production line. From 1999 till 2000, the A&SD process took place. Initially the project started to cover the range of T8 till T4. That means a product range with lamp-diameters from 8/12 to 4/12 inch. Research gave insight that T4 a diameter from 4/12 inch was not yet possible. From 2000 till 2001 the Product Realization Phase (PRP) was executed for the HTL production line. Production was introduced in 2001.

Mid 1999 the A&SD T8-T4 assignment started. From previous projects 85% of the knowledge was re-used. Interfaces were fixed. And the process existed of several issues that had to be solved. Issues existed of deployment of critical functions (e.g. coating, reduction of setup times). Total cost of this process was 2 till 3mln. Euro. Pilot studies and equipment for it are expensive if the chance that product would be a success is uncertain. 15 man were involved in Roosendaal. The reference architecture creation process lead-time was 1½ year. Early 2000, because the production machine is the bottleneck, range feasibility was done and functionality's were tested to prove solutions would work. Mid-end 2000 a robust platform was developed and released.

4.3.2 Context
In Philips Lighting 4 main Business Groups (BGs) are active.

BG Lamps	60% of Sales
BG Lighting Electronics	20%
BCU Automotive & Special lighting	10%
BCU Luminaries	10%

Lighting has a turnover of around 5 bln. Euro, with a Profit of around 0,5 bln. Main competitors are Osram and GE. The market for TL lamps is mainly business-to-business.

A main characteristic of BG Lamps in Philips Lighting is that it operates in a production process-technology driven market. There is a big focus production technology because production volumes are very high. This means that architectures in this context are strongly influenced by the requirements from the production process. In contrary of Philips CE that operates in an assembly driven market. In Philips CE the focus is at the products.

4.3.3 Main goal of architecture creation
The main goal of architecture creation is to deliver a new or extended product- and manufacturing platform with medium to high technical risks, possibly combined with medium to high market risks. This platform is able to produce the products and to produce those products as efficiently as possible.
The goals of the process are: test the best options, eliminating risks, prepare the development process to engineer concurrent, save costs and make time-to-market shorter.

4.3.4 Process
4.3.4.1 Input
The assignment has been the main document. In here the goals are set for the final result. Most assignments are to improve the production process. Besides this assignment the different requirement specifications provide input. Also the following documents were part of the input: A new lamp concept, for which the technical feasibility has been demonstrated and which has been evaluated for market attractiveness (applications, products), an idea for a (more of less completely) new manufacturing platform for an existing lamp concept, an existing product- or manufacturing platform, which needs to be improved (e.g., for cost reduction) or extended.

4.3.4.2 Activities

Architecture and standard design process at Philips Lighting is the same process as described in the speed documents at Philips CE. The process was divided in two main parts. I.e. functional analysis and architecture definition (mainly hardware).

The Architecture and standard design process exist mainly of creation of solutions for different issues (e.g. new functionality's, variation in design, cost down measures and the heating-curve of the glass is important and very complex) The processes to solve the issues were different dependent of the kind of issue. In one case 3 iterations of the cycle were necessary in the other case one cycle was enough. Or solutions for one issue were made parallel and the strongest survived.

Activities in the DVD+RW project are clustered in the same way as the reference model 1 is clustered. That means that there are eight main blocks of activities, see reference model 1 in appendix 1. Because of this clustering we could compare the activities of the projects with the activities in the reference model 1. Below the activities are described representative for each cluster.

Requirements development Identify and agree the (market-/application-/supply chain-) requirements for the product family, now and in the future.
Analyze and validate requirements Platform requirement specification for the new or improved platform to be developed: customer requirements for the platform, from an application, market, supply chain and financial perspective; including identification of the targeted range of the platform
Define scope of architecture Identify and agree the range of the product family: the (possibly) required diversity of products in the family Key process parameters identified & feasibility shown in industrially representative test-stand (Cp targets). Key equipment design parameters identified & understood (Cm).
Brainstorm architecture solutions Translate requirements to functionality: identify the functions that are critical with respect to requirements and/or diversity Make high-level functional architecture, zooming in into critical functions
Make detailed design Available technology, such as a proven lamp concept for which a platform will be developed or an existing platform that will be extended or improved in the project. Analyze the critical functions and interfaces of the platform to be developed and show that technical solutions for these critical functions are feasible, if necessary by applying lab testing. This part of the process aims at resolving high risks. A critical function is typically a technically high-risk area, for which no (sufficiently robust and/or cost-effective) solutions are available (yet).
Synthesize system element alternatives For the critical functions, assess the technology and the technological options that are available; decide which will be applied and/or explored in the project Make a work breakdown for the project, based on the need to develop technology for implementing the critical functions, key product parameters identified & understood, key component parameters identified & understood.
System analysis and optimization activities Identification of critical functions of the platform to be developed; i.e., the areas in the platform with the highest technical risks. risk management plan. Demonstrate the robustness of the platform, for its agreed range of application, if necessary by executing industrially representative pilot testing. This part of the process aims at resolving medium risks.
Selection of platform Milestone '0'

4.3.4.3 Output

The reference architecture was divided in the following chapters:
Marketing, technical issues, industrial production, purchasing, financial business case, future proof, Logistic requirements. Important are the Commercial Requirements specifications that exist mainly in user specifications and technical functional specifications. The main views are the Functional and Physical view.

4.3.5 Results

What is in the reference model and is not in the case study process

The following activities are in the reference model but not in the case study: Identify stakeholders. Develop & allocate standard design requirements. Develop interface requirements. Perform benchmark studies for competition requirements. Allocate requirements to the functions. Allocate requirements to the functions. Logical grouping of functionality's. Define environmental & design constraints. Define operations &support concept. Develop life cycle techniques & procedures.

Establish technical data package. Interface compatibility. Develop selection criteria. Analyze timing and resources. Analyze intellectual property / patent a/o standardization.

The case study model uses an intern model that is a first a his kind. Therefore it is possible that not all activities re mentioned. Arguments for differences could also be that in the case study activities are planned in a subsequent phase in the development process and therefor not mentioned in the reference architecture creation process of the TL-5 case study.

What is in the case study process and is not in the reference model
In the reference model supply chain analysis is not mentioned. Supply chain management becomes important in industry nowadays. A Project plan, with committed resources and budget, including estimate of budget for building pilot equipment (if applicable). Milestone checks are not mentioned in the reference model. Strategy and planning activities are mentioned neither.

As in paragraph 4.1.5 also here the argument could be that activities of the TL-5 reference architecture creation process are more specific than general valid activities, and therefor not mentioned in the reference model.

Other remarks
Product Data Management is important to use from the start, because different people use critical information. By this less communication problems will occur.
Because of the very large scale of production, Key components are of major importance.
Diversity of products is possible if you change the length of the tube and/or change the kind of powder to get other colors. +/- 85% of earlier projects as T8 and T12 is re-used.

4.4 Results of the case studies

The goals for this chapter were:

1. To get insight in the reference architecture creation process and context of the projects in the three case study's.
2. To validate the reference model 1
3. To improve the reference model 1 with additional activities.

The first goal is achieved and described in the case study's including the appendices. Also insight in the context of the project and the activities itself were showed.

For the second goal we saw in the case studies, that there were activities that have been described in the reference model and not done in the case studies. Though the reference model is a reference and not a recipe the model is validated as much as possible. you can see that activities are not necessary all the time. The kind of activities depends of the kind of project. Following the architects interviewed, the reference model is good.

For the third goal we focus on the activities that were done in the case studies and were not described in the reference model 1. These activities are described in table 4.1 and related to the eight main blocks of reference model 1. These activities will be included in reference model 2. Activities that don't match the different blocks are described in the other blocks. As we have decided that the scope of the reference model is from Architecture Start to Architecture defined, it is arguable if strategy and planning activities should be mentioned. Normally these activities are in advance or above the primary process. Because the process is of an improvising nature, it is possible that between these milestones still strategy and planning activities are done.

The activities shown in table 4.1 will be included in reference model 2 (= Appendix B).

Table 4.1 Activities done in the case study and not described in the reference model 1.

	Jaguar project	DVD+RW project	TL-5 Project
Requirements development			
Analyze and validate requirements	Service and repair strategy	The analysis of the risks	
Define scope of architecture	Hardware / software distinction		
Brainstorm architecture solutions	Define user interfaces, concept saving		
Make detailed design			
Synthesize system element alternatives			
System analysis and optimization activities			Supply chain analysis
Selection of platform	Business justification		

Planning	Project planning,	Project planning	Project planning, , milestone checks
Strategy	strategy activities, definition of industrial strategy		strategy activities
Costs	Industrial costs, NPV		

5. The Use and Implementation of the reference model

The previous chapters gave insight in what activities we can do to create a reference architecture. Theory in paragraph 3.2 and case studies in paragraph 4.1.2, 4.2.2 and 4.3.2 gave also insights of aspects and the context of architecting. In this chapter several aspects of this context are discussed for the persons involved. To be more specific, the following questions will be answered: How should system architects use the reference model?
How should PCP-office implement the reference model?

5.1 How to use the reference model (aspects and insights for system architects)

In this paragraph is described how system architects should use reference model 2 as described in Appendix B. The reference model is a comprehensive and detailed reference what activities should be done to create a reference architecture. The model is a reference so what activities should be selected and on what manner those activities should be deployed depends strongly on the insights and aspects described below of each certain project. Therefor should the way how to use the reference model be the responsibility of system architects themselves. (See also paragraph 3.2.1).

5.1.1 The Reference Architecture Process

Goal of process
The main goal of architecture creation is to achieve standardization within a defined range of products or to deliver a new or extended product- and manufacturing platform that could cover a range of products. Consequence of standardization will be cost down through reuse and more secure product development process. (See also paragraph 3.2.2).
The main goal of the architecture creation process is: to fasten time-to-market of its final product range, to eliminate the risks in a early phase (that in a later phase could cause problems in the realization and production phase, that will be expensive) and test the best options for the final result. In the end of the process the reference architecture should cover the checklist that is handled at milestone 'Architecture Defined' (AD).
Dependent of the project lower classified goals are defined. This will be different for each other project.

Type of process
The type of process that results in an architecture of a product family is dependant of three variables. A different process should be planned and walked through for each kind of variable. To estimate how much effort a project will take, these variables should be taken into account. Experience in this is vital.

- There should be a clear distinction between first of a kind, second generation and third generation of architectures. In a first of a kind project innovation is radical and in the second and third generation it is more incremental. In the first case most of the things should be developed from scratch in the second case reuse of data and know-how is possible and because of experience risks are better foreseen. In the DVD+RW case study, you could see that the process is less structured. Everything is less secure, so process is more ad-hoc. For the Jaguar case a structured process is inevitable. More people are involved, projects like this could easily be bigger than first of a kind projects. If the architecture could be characterized as "first of a kind", than the process is focused to be the first on the market. Speed will be the biggest driver. Because the earlier at the market, the bigger the margins. In marketing terminology you could speak of a potential "star". The DVD+RW case in paragraph 4.2 is such an architecture. If the architecture could be characterized as "third generation", than the process is focused to fulfill as much as possible on market needs against a low price. Cost saving will be the biggest driver.

Diversity will be the focusing issue. In marketing terminology you could speak of a "cash cow". Relatively seen The Jaguar case in paragraph 4.1 is such an architecture

- Important is the abstraction level of the architectures or in other words the specification level, will it only support the main issues, or are things already decided in detail. Over specification leads to costs in the beginning. Under specification leads to mistakes that will cost in the end. Somewhere there is an optimum. Also the number and size of the cycles in this iterative process have influence on the specification level. One linear process leads to over-specification, too many little cycle's leads to under-specification.

- Also the scope of the architectures leads to a different approach. Will the architecture cover one product or a whole product line. Is the architecture for products, processes or markets? In these approaches different issues will be important. The Size of the project is dependant of how insecure the results of the project will be. It could be possible that a third generation project is more extensive than a first of a kind project. If the size of a project increases the need for a structured process increases. (See also paragraph 3.2.4)

The process should be flexible to solve issues (e.g. new functionality's, varieties in design, cost down measures and for TL-5 case specifically the heating-curve of the glass is important and very complex) Through the pressure of time, architects are forced to make decisions. Architects should therefore make a prioritized list of issues to be solved. Dependant of this prioritized list, the planning of the process should be made and decisions should be taken.

Milestones
The Milestone between Architecture Start and Architecture Defined (e.g. in Jaguar project) is debatable. On the one hand it's a check if things are still going, as it should be. On the other hand the whole circus of people who have to agree should be played again. That takes a lot of effort. Therefor the number of milestones should be decided carefully. The main goal of a milestone is to see things are ok and to get management authorization like go/kill decisions. To many milestones takes to much effort, to small milestones takes to many risks.

5.1.2 The Reference Architecture

Views
Architectures are conveyed by all the different views. First the different viewpoints should be developed and defined clearly and in detail. The key issue here is that you should try to cover all relevant information in less as possible number of views. Otherwise people around and architects itself could loose the overview. Then views should be employed and communicated. Within Philips CE there isn't a structured selection and format of views, while this is the product of architecting and base to communicate such complex matters. Format for these documents can be: Viewpoint name; Stakeholders; Concerns; Viewpoint language; Source

The theoretical models described, do not clearly show distinction in hardware, software and mechanical views. The cases of Philips CE show this is one of the major distinctions. Therefor specific views should be employed to make this difference in Philips CE. (See also paragraph 3.2.5 to 3.2.7).

Ways of work and Terminology
Ways of work and terminology in case studies are very detailed and specific. In the theoretical models described all processes and terminology are very general. Because of the complexity of products, Philips CE could have benefits of a detailed description of its processes. Nowadays there is still different use of terms in the different BCU's. Effort should be made to synchronize all terms in Philips and make those terms as general as possible. This makes future communication easier.

Key components
During the process, the architecture should be worked-out in such a way that it forms a stable base for developing and manufacturing a whole family of products. This requires that at the end of this phase, for all the critical functions of the architecture, the key choices of the whole global range of applications have been established and the supply base has been frozen.
This may require extensive effort from some key suppliers in R&D and manufacturing skills. Joint identification of potential risks in the cross-functional project team, and a striving for a joint business win-win must be part of this process. Wrong supplier choices made in this phase can only be rectified by enormous costs afterwards

For this reason there are some purchasing characteristics:
Prepare and execute full supplier assessment in order to investigate whether suppliers are able to deliver at Philips CE standards. Manage relationships to establish mutual trust and by removing roadblocks such as cultural differences, insufficient communication approaches, lack of management support etc. Clarify and establish intellectual property issues and establish the framework for dealing with them during the course of co-development. Gain insight in suppliers cost structure and perform strategic cost management along the total supply chain with the suppliers. Lead the process for making agreements and contracts.

In this context architects should see when and how the decisions of key components should be made. In one case this could be in an early phase in the other case this is only possible in a later phase.

5.1.3 Documentation

Reuse and PDM
If Philips wants to focus on more reuse of its architecture, then a PDM system becomes more vital. The moment to deliver input in the PDM system will be the moment when the benefits of the input will exceed the effort that the input will take. On the one hand if you put the information in a PDM system in an early phase, lots of change and configuration management should be done that takes lots of effort. In the other hand knowledge is saved already in that early phase. Architects should make a trade-off to find an optimum.

5.2 How to implement the reference model (aspects and insights for PCP-office)

In this paragraph suggestions and points are made for the implementation of the reference model. In this point of view, implementation will mean the way the reference model could be used to help the processes in Philips CE. Processes that leads to a reference architecture. What should be done with this reference model 2, now we have this model in more detail?

5.2.1 The Reference Architecture Process

The reference model 2 is a comprehensive and detailed guideline to know what steps could be followed to walkthrough a Reference Architecture Process within Philips. It is possible however that projects don't need to follow every step in this model. Dependant of the projects and the information that is necessary to make a design. In each situation the responsible system architects should make a selection of the steps. This should be done in such a way that in the end a robust solution is possible.

Persons involved have enough experience and knowledge to know how the reference model 2 could be interpreted. Training of system architects how to use this model is not really necessary if the A&SD brochure [2] is provided with sufficient information. Information involves the reference model itself and the aspects and insights described in the previous paragraph. Planning by system architects is made with lots of common sense. Despite this great benefits or mistakes could be made by planning. So experiences in how this is done, and why decisions are made could be interesting for improvement in the future.

To ensure that system architects work with the reference model PCP-office should help the system architects with a sound planning of the activities and with getting support of its actors.

5.2.1.1 Planning

System architects and project owners are the persons who could make a selection out of the activities and put those activities in a time plan. System architects are the persons with up to date knowledge and have the best experience for the job. System architects know what things should be done to reach the business goals. For this reason all responsibility is in hands of a team around these persons.

Planning activities should be done by system architects too. Architects have the experience to estimate how sound in what time and in what order activities could be done best. Planning is strongly dependant of the project that is in account and therefore different in each other situation. People with long experience and the right knowledge have the best intuition to make a planning.

5.2.1.2 Support

Support for the planning is created by consensus. This could be created by good communication and clear appointments in the start of the project. Project management rules and guidelines are very useful in situations like this.

One of the tasks of the PCP-office is to stimulate the use of this reference model. This could be realized first by publishing the reference model in the Architecture and Standard Design Process brochure[2] and secondly give feedback after audits that are done.

5.2.2 Testing and Maintenance of the reference model

First the reference model should be tested. PCP-office should check future projects to look if the model is used and is good enough to work with. This should not take lots of effort if timing is right. Best timing is when Planning is made. Within a day the model is checked during the planning for the new project. System Architects should give feedback during this planning to PCP-office so improvements could be made.

System architects are also responsible for the maintenance of the model. Feedback during the process from system architects should be noticed. With this feedback, actions should be taken to improve the reference model and if possible to improve the process of the project.

5.2.3 Product Data Management

The idea that activities could be executed with support of the product management system, without extra effort of the architects is an utopia. Investments are necessary before profit could be made. It is therefore recommendable to put effort in this product data management system. It will be profitable when one could reuse the information.
Philips should document information of related matters. For example: decisions that are made why certain activities are important or skipped. By this means the architects could build a kind of knowledge bank, so that in the future Philips is less dependable of the persons who have the knowledge and experience in their mind. This is still a weak spot.

5.2.4 Key components, physical view functional view and requirements view

Information about Key components, physical view, functional view and requirements view of the reference architecture can be documented if information is robust enough. The most adequate moment in time should be the decision or trade-off of the system architect and his team. This is project dependant so it would not be wise to comment more than this.

6 Conclusions and Recommendations

In this chapter conclusions are described and recommendations are made to Philips CE. Points that are important for future business success.

6.1 Conclusions

The conclusion of the assignment that has been defined in chapter 2 is as follow:

A reference model has been developed and validated for the reference architecture creation process. This reference model is more detailed than the initial process out of the SPEED documents. Also common terminology is created.

This reference model is a comprehensive and detailed reference or guideline for architects to plan a process or life cycle model of the reference architecture creation process throughout Philips CE. Terminology used is as much as possible standardized and explained in the Appendix C.

The reference model was constructed by looking to theoretical models in chapter 3 and has been validated by three case studies representative for Philips CE. Case studies were described in chapter 4.

To complete the answer of the first research question on a detailed process description and what activities could be executed with support of the PDM system, the following is concluded.

Architects themselves could decide best whether activities can be executed with support of the product data management system or not.

What process activities could be executed with support of the Product Data Management system and without extra effort of the architects should be decided by the architects themselves in each specific situation. Architects are confronted daily with the activities and have the experience when information of these activities is *useful*, to put in the product data management system. Criteria for useful depends on need for communication, insight or need for reuse.

To answer the second research question on the most adequate moments in time to include data in PDM, the following is concluded.

The most adequate moments to include data about key components, physical view, functional view and requirements view of the reference architecture in a product data management system is different in each certain situation and should be decided by the architects themselves for that certain situation.

Architects themselves could decide best when are the most adequate moments to include data about key components, physical view, functional view and requirements view of the reference architecture. Architects themselves could define best when data is *in right format and robust enough*, so that effort in configuration management does not exceed the benefits of the time data is included earlier. This is dependant of each certain situation.

The literature described in chapter 3 and the three case study's described in chapter 4 delivered extra valuable insight in the context of the process and different aspects of architecting.

For the Jaguar case the beginning of a detailed process description is developed. The process is described in appendix G.

6.2 Recommendations

In this paragraph recommendations for Architects and recommendations for PCP-office are described.

6.2.1 Recommendations for architects

Use the reference model!

This reference model in appendix B is a comprehensive and detailed reference or guideline for architects to plan the process or life cycle model of reference architecture creation. Use of the reference model will reduce risks that certain activities are not executed.

Study, analyze and select the activities of the reference model

Architects should study, analyze and select the activities of the reference model before they start to plan the process for reference architecture creation. The case studies showed different kind of processes for each situation. The insights in chapter 5 could be of great help by selecting activities. By this a right portfolio of activities could be selected to come to an optimal result with a minimal effort.

Maintain and Improve Terminology

Ways of work and terminology in the case studies were very detailed and specific. In the theoretical models described all processes and terminology are very general. Because of the complexity of products, Philips CE will have benefits from a detailed description of its processes against relatively low cost . Nowadays there is still different use of terms in the different BCU's. Effort should be made to synchronize most terms in Philips and make those terms as general as possible. The few terms that are really specific to one case, could also be gathered and communicated with PCP-office.

Check for different projects where and how many milestones should be set

The Milestone between Architecture Start and Architecture Defined (e.g. in Jaguar case) is debatable. On the one hand it's a check if things are still going, as it should be. On the other hand the whole circus of people who have to agree should be played again. That takes a lot of effort. Therefor the number of milestones should be decided carefully. The main goal of a milestone is to see things are ok and to get management authorization like go/kill decisions. Too many milestones takes too much effort, too few milestones takes too many risks.

Let system architects decide the moment whether or not information should be included in the Product Data Management system

Information about Key components, physical view, functional view and requirements view of the reference architecture could be documented if information is robust enough. The most adequate moment in time should be the decision or trade-off of the system architect and his team.

Clear viewpoints and views should be developed in detail.

Important is in the product creation process that the product will be communicated. Today many things are communicated informal in little parts and/or face to face. I think great benefits are possible when:

First: Viewpoints will be developed, with viewpoints it is important between which actors communication should take place and what information should be communicated.
Second: Views will be developed, with views you should aim to a most efficient way the necessary detailed information could be communicated. These views should be the base to reuse parts of reference architectures for future reference architectures.

Within Philips there isn't a detailed selection and format of views nowadays. Format for these documents can be: Viewpoint name; Stakeholders; Concerns; Viewpoint language; Source.

Architects should document information of related matters of reference architectures.

It is recommendable to put effort in the product data management system. It will be profitable and value will be added, when you could re-use the information. Related matters can be decisions that are made why certain activities are important or skipped. Also matters that are mentioned in the reference model but not yet or insufficient highlighted in the practical situations and visa versa. By this means the architects could build a kind of knowledge bank, so that in the future Philips is less dependable of the persons who have the knowledge and experience in their mind. This is still a weak spot in the organization of the BCU TV up-market. Architects should see the need to describe knowledge. If they see the need there will be the will to describe this knowledge.

Jaguar architects should improve the process model in Appendix G.

For the Jaguar case, a process description is made in Appendix G. Jaguar project has the most detailed process studied from the case studies. Because of the specific terms and concrete activities it is maybe useful to use an separate and own model as base for future research besides the reference model 2.

6.2.2 Recommendations for PCP-Office

PCP-office should motivate system architects by using the reference model

System architects are the main responsible figures that could have influence on the planning of the reference architecture process. System architects should therefore be motivated to use this reference model. They should be convinced in the benefits using this model.

PCP- office should test the reference model

First the reference model should be tested. In the following project I recommend Philips CE to look carefully to the steps of the reference model to get inspiration for the way to follow. This should not take lots of effort. Planning should be made anyway, and with help of the reference model, you're about sure very little will be forgotten. Within a day the model is checked with the planning for the new project. E.g. a pilot project could be organized to test the model for usability.

PCP- office should maintain the reference model

System Architects should give feedback to PCP-office so improvements could be made. PCP-office is also responsible for the maintenance of the model. With this feedback, actions should be taken to improve the reference model. It would be wise to get feedback of the process each time a planning is made for a new project and also during the process (e.g. at milestones). By this means, data could be collected in the most critical phase. The difficulty remains that each project is different. But the general way the reference model is written, all kind of projects should have sufficient data.

Get feedback from architects and maintain and improve terminology

Architects should also see the need to give feedback and describe knowledge. If they see the need there will be the will to describe this knowledge. Than added value will be created. Taking audits is a good way to do this.

Document insights out of feed-back and audits of the future projects.

Now knowledge is lacking to do sufficient research. For future research insights out of feed back and audits of the reference architecture creation projects should be documented by PCP-office. By this means knowledge could be collected and the future process could be improved.

Future and further research on this field should be supported initially by the BCU or department where the process takes place.

Improvement projects will be more efficient and more feasible when direct support and responsibility lies in the hands of the BCU or departments where the process takes place. By this means more detailed information is within shorter reach. And people are more involved in the project.

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Contents of Appendix

Appendix A

Reference Model 1

	Reference Model 1	PCP-model	THEORY					
			CMMI	S E G	Win Win	Waterfall	Jacobson	RUP
	Requirements Development		Yes,4			yes	yes	yes
1	Collect assignment, LTPP & F/F roadmaps	Yes,1						
2	Analyze assignment and previous documents related to requirements development	Yes,2						
3	Elicit needs and latent customer needs	Yes,7	Yes,2					
4	Collect stakeholders requirements			Yes,1	yes			
5	Develop customer requirements		Yes,1,3					
6	Develop architecture requirements		Yes,5					
7	Develop standard design requirements		Yes,6					
8	Develop interface requirements		Yes,7	Yes,8				
9	Develop performance requirements			Yes,14				
10	Perform benchmark study for competition requirements	Yes,14						
11	Define a set of key drivers	Yes,3						
12	Define measures of effectiveness			Yes,7				
	Analyze and validate requirements		Yes,8,11	Yes,9	yes			
13	Allocate standard design requirements		Yes,6					
14	Analyze requirements to achieve balance		Yes,12					
15	Validate requirements with comprehensive methods		Yes,13					
16	Define potential functions			Yes,12				
17	Allocate requirements to the functions	Yes,10						
18	Perform logical grouping of functionality	Yes,9		Yes,10				
19	Perform detailed functional requirement analysis	Yes,8						
20	Establish operational concepts and scenarios		Yes,9					
21	Establish a definition of required functionality		Yes,10	Yes,8				
	Define scope of architecture				yes			
22	Clarify domain and diversity	Yes,5,24						
23	Define system mission / objective			Yes,2				
24	Clarify target platform lifetime	Yes,6						
25	Develop life cycle techniques & procedures			Yes,27				
26	Define system functions			Yes,12				
27	Define system requirements	Yes,4						
28	Define system scenarios			Yes,3				
29	Define system boundary			Yes,4				
30	Define environmental & design constraints	Yes,22		Yes,5				
31	Define operations & support concept			Yes,6				
32	Establish a draft system requirement specification	Yes,11						

	Brainstorm architecture solutions	Yes,15			yes			
33	Assess technology alternatives			Yes,20		yes		
34	Develop hierarchical model of layered system	Yes,19	Yes,19					
35	Define system states & modes concepts and scenarios		Yes,16	Yes 11				
36	Design interfaces using criteria	Yes,18	Yes,21					
37	Define functional interfaces	Yes,17		Yes 13				
38	Establish technical data package		Yes,20					
	Make detailed design					yes	yes	yes
39	Develop detailed alternative solutions	Yes,12	Yes,14,15,18					
40	Identify key requirements and constraints	Yes,13						
	Synthesize system element alternatives			Yes,21				
41	Allocate functions to system elements			Yes,22				
42	Allocate constraints to system elements			Yes,23				
43	Define physical interfaces	Yes,17		Yes,24				
44	Integrate system elements			Yes,29		yes		
45	Perform architectural decomposition at a subsequent level of detail	Yes,30						
46	Cover design for manufacturing and logistics issues concurrently	Yes,31						
47	Analyze key components co-design, design-in	Yes,32						
48	Develop system models			Yes,31				
49	Refine work breakdown structure (WBS)			Yes,26				
50	Perform Make, Buy, or Reuse Analyses		Yes,22					
51	Check requirements compliance			Yes,28				
52	Ensure Interface Compatibility		Yes,30					
	System analysis and optimization activities:			Yes,30	yes		Yes	yes
53	Develop selection criteria		Yes,15					
54	Analyze performance and scenarios	Yes,29		Yes,15				
55	Analyze timing & resources			Yes,16				
56	Analyze failure mode effects and criticality			Yes,17				
57	Define fault detection & recovery behavior			Yes,18				
58	Analyze risks	Yes,23		Yes,33				
59	Analyze price	Yes,26						
60	Analyse capacity constraints	Yes,27						
61	Analyse intellectual property/patent a/o standardization issues	Yes, 28						
62	Perform system effectiveness and cost effectiveness analysis			Yes,32				
63	Risk evaluation			Yes,33				
64	Trade studies	Yes,20		Yes,34				
65	Analyse platform requirements	Yes,21						
66	Analyse industrial process constraints	Yes,25						
	Selection of platform							
67	Define platform and architecture	Yes, 35	Yes,17					

68	Perform iterations (SPIRAL MODEL) refine requirements	Yes,33	yes	yes	yes		yes	
69	Update outline design, prototype, simulation, test, verify until robust solution	Yes,34						
	Others							
70	Feasibility study					yes		
71	identify stakeholders				yes			

If there exist a similar step in the models with my suggested model than "yes" is written down. In this way you could see gaps and similarities. The number behind yes is the number that is linked with the process steps of the specific models. For example: activity 69 is comparable to PCP model activity 34.

Please Note: the activities in this model that are numbered are not sequential. It is meant to finish activities concurrently!

Appendix B

Reference Model 2

This Reference model 2 starts with the first block of activities that are strongly related with the primary process of the reference architecture creation process in the second block. The first block are the so called management activities necessary to control the activities of the second block.

		PCP	THEORY						CASE STUDIES		
	Reference Model 2, Block 1	Ref.Arch Creation	CMMI	S E G	Win Win	Waterfall	Jacobson	RUP	Jaguar	DVD +RW	TL-5
	Strategy										
78	*Define industrial strategy*								Yes		
79	*Strategy activities*										
	Feasibility										
80	Feasibility study of the architecture creation process					Yes					Yes
81	*Define Industrial Costs, NPV*								Yes		
	Planning										
82	*Make project planning of the architecture creation process*								Yes	Yes	Yes
83	*Milestones checks*										Yes
	Others										
84	identify stakeholders				Yes						

		PCP	THEORY						CASE STUDIES		
	Reference Model 2, Block 2	Ref.Arch Creation	CMMI	S E G	Win Win	Waterfall	Jacobson	RUP	Jaguar	DVD +RW	TL-5
	Requirements Development		Yes,4			Yes	Yes	Yes		Yes	
1	Collect assignment, LTPP & F/F roadmaps	Yes,1							Yes	Yes	Yes
2	Analyze assignment and previous documents related to requirements development	Yes,2							Yes	Yes	Yes
3	Elicit needs and latent customer needs	Yes,7	Yes,2						Yes	Yes	Yes
4	Collect stakeholders requirements			Yes,1	Yes				Yes		Yes
5	Develop customer requirements		Yes,1,3						Yes		Yes
6	Develop architecture requirements		Yes,5						Yes		Yes
7	Develop standard design requirements		Yes,6								
8	Develop interface requirements		Yes,7	Yes,8					Yes		
9	Develop performance requirements			Yes,14					Yes		Yes
10	Perform benchmark study for competition requirements	Yes,14							Yes	Yes	
11	Define a set of key drivers	Yes,3							Yes	Yes	
12	Define measures of effectiveness			Yes,7							
	Analyze and validate requirements		Yes,8,11	Yes,9	Yes						
13	Allocate standard design requirements		Yes,6								
14	Analyze requirements to achieve balance		Yes,12								Yes

15	Validate requirements with comprehensive methods		Yes,13						Yes		Yes
16	Define potential functions			Yes,12					Yes		Yes
17	Allocate requirements to the functions	Yes,10							Yes	Yes	
18	Perform logical grouping of functionality	Yes,9		Yes,10					Yes	Yes	
19	Perform detailed functional requirement analysis	Yes,8							Yes	Yes	Yes
20	Establish operational concepts and scenarios		Yes,9						Yes		Yes
21	Establish a definition of required functionality		Yes,10	Yes,8					Yes		Yes
22	*Service and repair strategy*								Yes		
23	*Analysis of the risks*									Yes	
	Define scope of architecture				Yes						
24	Clarify domain and diversity	Yes,5,24							Yes	Yes	Yes
25	Define system mission / objective			Yes,2					Yes		Yes
26	Clarify target platform lifetime	Yes,6							Yes	Yes	Yes
27	Develop life cycle techniques & procedures			Yes,27							
28	Define system functions			Yes,12					Yes		Yes
29	Define system requirements	Yes,4							Yes	Yes	Yes
30	Define system scenarios			Yes,3					Yes		Yes
31	Define system boundary			Yes,4					Yes		Yes
32	Define environmental & design constraints	Yes,22		Yes,5					Yes	Yes	
33	Define operations & support concept			Yes,6							
34	Establish a draft system requirement specification	Yes,11							Yes	Yes	Yes
35	*Make Hardware / Software distinction*								Yes		
	Brainstorm architecture solutions	Yes,15			Yes				Yes	Yes	Yes
36	Assess technology alternatives			Yes,20		Yes			Yes		Yes
37	Develop hierarchical model of layered system	Yes,19	Yes,19						Yes	Yes	Yes
38	Define system states & modes concepts and senarios		Yes,16	Yes 11					Yes		Yes
39	Design interfaces using criteria	Yes,18	Yes,21						Yes	Yes	Yes
40	Define functional interfaces	Yes,17		Yes 13						Yes	Yes
41	Establish technical data package		Yes,20						Yes		
42	*Define User Interfaces*								Yes		
43	*Concept Saving*								Yes		
	Make detailed design					Yes	Yes	Yes			
44	Develop detailed alternative solutions	Yes,12	Yes,14, 15,18						Yes	Yes	Yes
45	Identify key requirements and constraints	Yes,13							Yes	Yes	Yes
	Synthesize system element alternatives			Yes,21							
46	Allocate functions to system elements			Yes,22					Yes		
47	Allocate constraints to system elements			Yes,23							Yes
48	Define physical interfaces	Yes,17		Yes,24					Yes	Yes	Yes
49	Integrate system elements			Yes,29		Yes			Yes		Yes
50	Perform architectural decomposition at a subsequent level of detail	Yes,30								Yes	Yes

51	Cover design for manufacturing and logistics issues concurrently	Yes,31								Yes	Yes
52	Analyze key components: co-design, design-in	Yes,32							Yes	Yes	Yes
53	Develop system models			Yes,31							Yes
54	Refine work breakdown structure (WBS)			Yes,26					Yes		Yes
55	Perform Make, Buy, or Reuse Analyses		Yes,22						Yes		Yes
56	Check requirements compliance			Yes,28					Yes		Yes
57	Ensure Interface Compatibility		Yes,30								
	System analysis and optimization activities:			Yes,30	Yes		Yes	Yes			
59	Develop selection criteria		Yes,15						Yes		
60	Analyze performance and scenarios	Yes,29		Yes,15					Yes		Yes
61	Analyze timing & resources			Yes,16					Yes		
62	Analyze failure mode effects and criticality			Yes,17					Yes		Yes
63	Define fault detection & recovery behavior			Yes,18							Yes
64	Analyse risks	Yes,23		Yes,33					Yes	Yes	Yes
65	Analyse price	Yes,26							Yes	Yes	Yes
66	Analyse capacity constraints	Yes,27							Yes	Yes	Yes
67	Analyse intellectual property/patent a/o standardisation issues	Yes, 28							Yes	Yes	
68	Perform system effectiveness and cost effectiveness analysis			Yes,32							Yes
69	Risk evaluation			Yes,33					Yes		Yes
70	Trade studies	Yes,20		Yes,34							
71	Analyse platform requirements	Yes,21								Yes	Yes
72	Analyse industrial process constraints	Yes,25								Yes	Yes
73	*Analyse Supply Chain*										Yes
	Selection of platform										
74	Define platform and architecture	Yes, 35	Yes,17						Yes	Yes	Yes
75	Perform iterations (SPIRAL MODEL) refine requirements.	Yes,33	Yes	Yes	Yes		Yes		Yes	Yes	Yes
76	Update outline design, prototype, simulation, test, verify until robust solution	Yes,34							Yes	Yes	Yes
77	*Make Business Justification*								Yes		

Please Note: the activities in this model that are numbered are not sequential. It is meant to finish activities concurrently!

If there exist a similar step in the models with my suggested model than "yes" is written down. In this way you could see gaps and similarities. The number behind yes is the number that is linked with the process steps of the specific models. For example: activity 69 is comparable to CMMI model activity 33.

The activities in *italic* are added as the result of the case studies.

Appendix C

Activities of the Reference Model

Requirements Development Establish a historical database of technical decisions and requirements for future reference. The database will be the primary means for maintaining requirements traceability. All product and process requirements should be maintained in this database. Develop a requirements traceability matrix as a report from the database. The RTM will map the requirements to subsystems, Configuration items, and functional areas. The RTM should be reissued on a regular basis to communicate the latest requirements and allocations. Identify technical budgets that need to be tracked. Develop a philosophy and approach for managing the technical margins. Reallocate margin as appropriate according to risk assessments. Ensure that the allocated requirements and the results from the synthesis tasks are consistent and traceable to the work packages in the WBS. Refine the WBS as required. Ensure that consistency is maintained between the statement of work, the organizational breakdown structure, and the architecture block diagram. Also ensure that the cost objectives are being met in accordance with the cost breakdown structure.

Collect assignment, Collect assignment

LTPP & F/F roadmaps Long term project plan and Function Feature Roadmap

Analyze assignment and previous documents related to the reference architecture Analyze assignment and previous documents related to the reference architecture

Elicit needs and latent customer needs Elicit stakeholder needs, expectations, constraints, and interfaces for all phases of the product life cycle. Eliciting goes beyond collecting requirements by proactively identifying additional requirements not explicitly provided by customers. Additional requirements should address the various product life-cycle activities and their impact on the product. [PA157.IG101.SP102.N102]

Collect stakeholders requirements The basic activity addresses the receipt of requirements that a customer provides to define what is needed or desired. These requirements may or may not be stated in technical terms. They should address the various product life-cycle activities and their impact on the product. [PA157.IG101.SP101.N101]

Develop customer requirements Stakeholder needs, expectations, constraints, and interfaces are collected and translated into customer requirements. The various inputs from the customer must be consolidated, missing information must be obtained, and conflicts must be resolved in documenting the recognized set of customer requirements. The customer requirements may include needs, expectations, and constraints with regard to verification and validation. [PA157.IG101.SP103.N101]
The needs of stakeholders (e.g., customers, end users, suppliers, builders, and testers) are the basis for determining customer requirements. The stakeholder needs, expectations, constraints, interfaces, operational concepts, and product concepts are analyzed, harmonized, refined, and elaborated for translation into a set of customer requirements. [PA157.IG101.N101]

Develop architecture requirements Customer requirements are refined and elaborated to develop architecture and architecture-component requirements. Customer requirements are analyzed in conjunction with the development of the operational concept to derive more detailed and precise sets of requirements called "product and product-component requirements." Product and product-component requirements address the needs associated with each product life-cycle phase. Derived requirements arise from constraints, consideration of issues implied but not explicitly stated in the customer requirements baseline, and factors introduced by the selected architecture, the design, and the developer's unique business considerations. The requirements are reexamined with each successive, lower level set of requirements and functional architecture, and the preferred product concept is refined. [PA157.IG103.N101]

The requirements are allocated to product functions and product components including objects, people, and processes. The traceability of requirements to functions, objects, tests, issues, or other entities is documented. The allocated requirements and functions are the basis for the synthesis of the technical solution. As internal components are developed, additional interfaces are defined and interface requirements established. [PA157.IG103.N102]

Develop standard design requirements Develop standard design requirements

Develop interface requirements Interfaces between functions (or between objects) are identified. Functional interfaces may drive the development of alternative solutions described in the Technical Solution process area. [PA157.IG103.SP103.N101]

Interface requirements between products or product components identified in the product architecture are defined. They are controlled as part of product and product-component integration and are an integral part of the architecture definition. [PA157.IG103.SP103.N102]

Develop performance requirements Develop performance requirements

Perform benchmark study for competition requirements Perform benchmark study for competition requirements

Define a set of key drivers Define a set of key drivers

Define measures of effectiveness Identify and document the most critical performance parameters required to meet the operational requirements and develop relationships between those parameters that drive design. MOE's are used at operational level to assess the value (or utility) of the system. Provide these MOE's to System Engineering control for assessing technical program progress.

Analyze and validate requirements

The requirements are analyzed and validated, and a definition of required functionality is developed

The specific practices of the Analyze and Validate Requirements specific goal support the development of the requirements in both the Develop Customer Requirements specific goal and the Develop Product Requirements specific goal. The specific practices associated with this specific goal cover analyzing and validating the requirements with respect to the user's intended environment. [PA157.IG102.N104]

Analyses are performed to determine what impact the intended operational environment will have on the ability to satisfy the stakeholders' needs, expectations, constraints, and interfaces. Considerations such as feasibility, mission needs, cost constraints, potential market size, and acquisition strategy must all be taken into account, depending on the product context. A definition of required functionality is also established. All specified usage modes for the product are considered, and a timeline analysis is generated for time-critical sequencing of functions. [PA157.IG102.N101]

The objectives of the analyses are to determine candidate requirements for product concepts that will satisfy stakeholder needs, expectations, and constraints; and then translate these concepts into requirements. In parallel with this activity, the parameters that will be used to evaluate the effectiveness of the product are determined based on customer input and the preliminary product concept. [PA157.IG102.N102]

Requirements are validated to increase the probability that the resulting product will perform as intended in the use environment. [PA157.IG102.N103]

Allocate standard design requirements The requirements for product components of the defined solution include allocation of product performance; design constraints; and fit, form, and function to meet requirements and facilitate production. In cases where a higher level requirement specifies performance that will be the responsibility of two or more product components, the performance must be partitioned for unique allocation to each product component as a derived requirement. [PA157.IG103.SP102.N101]

Analyze requirements to achieve balance Analyze requirements to balance stakeholder needs and constraints. [PA157.IG102.SP104] Stakeholder needs and constraints can address cost, schedule, performance, functionality, reusable components, maintainability, or risk. [PA157.IG102.SP104.N102]

Validate requirements with comprehensive methods Validate requirements to ensure the resulting product will perform as intended in the user's environment using multiple techniques as appropriate. [PA157.IG102.SP106] In the staged representation, this specific practice takes the place of the Validate Requirements specific practice. Requirements validation is performed early in the development effort to gain confidence that the requirements are capable of guiding a development that results in successful final validation. This activity should be integrated with risk management activities. Mature organizations will typically perform requirements validation in a more sophisticated way and will broaden the basis of the validation to include other stakeholder needs and expectations. These organizations will typically perform analyses, simulations, or prototypes to ensure that requirements will satisfy stakeholder needs and expectations. [PA157.IG102.SP106.N102]

Define potential functions Define potential functions

Allocate requirements to the functions Allocate requirements to the functions

Perform logical grouping of functionality Perform logical grouping of functionality

Perform detailed functional requirement analysis Perform detailed functional requirement analysis

Establish operational concepts and scenarios A scenario is a sequence of events that might occur in the use of the product, which is used to make explicit some of the needs of the stakeholders. In contrast, an operational concept for a product usually depends on both the design solution and the scenario. For example, the operational concept for a satellite-based communications product is quite different from one based on landlines. Since the alternative solutions have not usually been defined when preparing the initial operational concepts, conceptual solutions are developed for use when analyzing the requirements. The operational concepts are refined as solution decisions are made and lower level detailed requirements are developed. [PA157.IG102.SP101.N101]

Just as a design decision for a product may become a requirement for product components, the operational concept may become the scenarios (requirements) for product components. [PA157.IG102.SP101.N102]

The scenarios may include operational sequences, provided those sequences are an expression of customer requirements rather than operational concepts. [PA157.IG102.SP101.N103]

Establish a definition of required functionality The definition of functionality, also referred to as "functional analysis," is the description of what the product is intended to do. The definition of functionality can include actions, sequence, inputs, outputs, or other information that communicates the manner in which the product will be used. [PA157.IG102.SP102.N101]

Functional analysis is not the same as structured analysis in software development and does not presume a functionally oriented software design. In object-oriented software design, it relates to defining the services. The definition of functions, their logical groupings, and their association with requirements is referred to as a functional architecture. [PA157.IG102.SP102.N102]

Define scope of architecture Define scope of architecture

Clarify domain and diversity Clarify domain and diversity

Define system mission / objective Define system mission / objective

Clarify target platform lifetime Clarify target platform lifetime

Develop life cycle techniques & procedures Develop life cycle techniques & procedures

Define system functions Define system functions

Define system requirements Define system requirements

Define system scenarios Define the expected scenarios of the system. From a black box perspective, define the stimuli to be encountered and response to each stimulus. Prioritize these scenarios according to the probability of occurrence and severity of strain on the system. The system test philosophy and approach will be based on these system scenarios. Test cases will be developed from these scenarios. Define the business model that determines the key "success criteria" for the targeted market segments.

Define system boundary Define the internal and external elements that will be involved in accomplishing the system purpose or mission(s) and the boundaries of the system.

Define the system boundary in terms of both space and time. What are its physical boundaries? What are its operational boundaries? When does the system start performing its mission or objective? When wil the system(or its components) be disposed of?

Define environmental & design constraints Identify and document the constraints that will limit or define the system 's performance or design, including cost constraints. Design-to-Cost (DTC) goals should be established. The hierarchy of DTC goals will be documented in a cost breakdown structure (CBS)

The design constraints should include such "non-functional" requirements as power, volume, weight, dimensions, etc. The environmental constraints should be defined for all system scenarios and for all primary functions.

Define operations & support concept Identify and document the operational andlogistics support approaches or constraints that will drive design. The support concept development is part of the logistics support analysis (LSA) process. Document the concepts in an operational concept document.

Establish a draft system requirement specification

Outline design The purpose of Technical Solution is to design, develop, and implement solutions to requirements. Solutions, designs, and implementations encompass products, product components, and product-related life-cycle processes either singly or in combinations as appropriate. [PA160]

Brainstorm architecture solutions Brainstorm architecture solutions

Assess technology alternatives Assess technology alternatives

Develop hierarchical model of layered system

Architecture definition is driven from a set of architectural requirements developed during the requirements development processes. These requirements express the qualities and performance points that are critical to the success of the product. The architecture defines structural elements and coordination mechanisms that either directly satisfy requirements or support the achievement of the requirements as the details of the product design are established. Architectures may include standards and design rules governing development of product components and their interfaces as well as guidance to aid product developers. Specific practices in the Select Product-Component Solutions specific goal contain more information about using product architectures as a basis for alternative solutions. [PA160.IG102.SP101.N102]

Define system states & modes concepts and scenarios
Integrate the operational concepts and scenarios produced by various individuals or groups for each level of physical product decomposition. [PA160.IG101.SP103.AMP101] Operational concepts and scenarios are evolved to facilitate the selection of product-component solutions that, when implemented, will satisfy the intended use of the product. Operational concepts and scenarios document the interaction of the product components with the environment, users, and other product components, regardless of engineering discipline. They should be documented for operations, product deployment, delivery, support (including maintenance and sustainment), training, and disposal and for all modes and states. [PA160.IG101.SP103.N101]

Design interfaces using criteria Design comprehensive product-component interfaces in terms of established and maintained criteria. [PA160.IG102.SP105] In the staged representation, this specific practice takes the place of the Establish Interface Descriptions specific practice.

Define functional interfaces Define functional interfaces

Establish technical data package Establish and maintain a technical data package. [PA160.IG102.SP103] A technical data package provides the developer with a comprehensive description of the product or product component as it is developed. Such a package also provides procurement flexibility in a variety of circumstances such as performance-based contracting or build to print. [PA160.IG102.SP103.N102]

Make detailed design Make detailed design

Develop detailed alternative solutions Detailed alternative solutions are an essential concept of the Technical Solution process area. They provide more accurate and comprehensive information about the solution than non-detailed alternatives. For example, characterization of performance based on design content rather than on simple estimating enables effective assessment and understanding of environment and operating concept impacts. Alternative solutions need to be identified and analyzed to enable the selection of a balanced solution across the life of the product in terms of cost, schedule, and technical performance. These solutions are based on proposed product architectures that address critical product qualities. Specific practices associated with the Develop the Design specific goal provide more information on developing potential product architectures that can be incorporated into alternative solutions for the product. [PA160.IG101.SP102.N104]

Identify key requirements and constraints Identify key requirements and constraints

Synthesize system element alternatives Synthesize system element alternatives

Allocate functions to system elements Allocate functions to system elements

Allocate constraints to system elements Allocate constraints to system elements

Define physical interfaces Define physical interfaces

Integrate system elements Integrate system elements

Perform architectural decomposition at a subsequent level of detail

Cover design for manufacturing and logistics issues concurrently Cover design for manufacturing and logistics issues concurrently

Analyze key components: co-design, design-in Analyze key components: co-design, design-in

Develop system models Develop system models

Refine work breakdown structure (WBS) Refine work breakdown structure (WBS)

Perform Make, Buy, or Reuse Analyses Evaluate whether the product components should be developed, purchased, or reused based on established criteria. [PA160.IG102.SP106]

Check requirements compliance Check requirements compliance

Ensure Interface Compatibility The product component interfaces, both internal and external, are compatible. Many product integration problems arise from unknown or uncontrolled aspects of both internal and external interfaces. Effective management of product component interface requirements, specifications, and designs helps ensure that implemented interfaces will be complete and compatible.

System analysis and optimization activities: analyze system and optimize activities

Develop selection criteria Selection criteria are influenced by a wide variety of factors driven by the requirements imposed on the develop program as well as the life cycle of the product. For example, criteria related to mitigating cost and schedule risks may influence a greater preference for COTS solutions provided such selections do not result in unacceptable risks in the remaining product components to be developed. When using existing items, such as COTS, either with or without modification, criteria dealing with diminishing sources of supply or technological obsolescence should be examined as well as criteria capturing the benefits of standardization, maintaining relationships with suppliers and so forth. The criteria used in selections should provide a balanced approach to costs, benefits, and risks.

Analyze performance and scenarios Analyze performance and scenarios

Analyze timing & resources Analyze timing & resources

Analyze failure mode effects and criticality Analyze failure mode effects and criticality

Define fault detection & recovery behavior Define fault detection & recovery behavior

Analyze risks Analyze risks

Analyze price Analyze price

Analyze capacity constraints Analyze capacity constraints

Analyze intellectual property/patent a/o standardization issues Analyze intellectual property/patent a/o standardization issues

Perform system effectiveness and cost effectiveness analysis Perform system effectiveness and cost effectiveness analysis

Risk evaluation Risk evaluation

Trade studies Trade studies

Analyze platform requirements Analyze platform requirements

Analyze industrial process constraints Analyze industrial process constraints

Selection of platform Selection of platform

Define platform and architecture Define Platform and architecture that best satisfy the criteria establishes the requirement allocations to architecture components. Lower level requirements are generated from the selected alternative and used to develop the product-component design. Interface requirements among product components are described, primarily functionally. Physical interface descriptions are included in the documentation for interfaces to items and activities external to the product. [PA160.IG101.SP104.N101]

The description of the solutions and the rationale for selection are documented. The documentation evolves throughout development as solutions and detailed designs are developed and those designs are implemented. Maintaining a record of rationale is critical to downstream decision making. Such records keep downstream stakeholders from redoing work and provide insights to apply technology as it becomes available in applicable circumstances. [PA160.IG101.SP104.N102]

Update outline design, prototype, simulation, test, verify until robust solution

Feasibility study The possibility to do or achieve.

Identify stakeholders Select relevant stakeholders from customers, end users, developers, producers, testers, suppliers, marketers, maintainers, disposal personnel, and others who may be affected by, or may affect, the product as well as the process

Perform iterations (SPIRAL MODEL) refine requirements.

Glossary of terms:

derived requirements	Requirements that are not explicitly stated in the customer requirements, but are inferred (1) from contextual requirements (e.g., applicable standards, laws, policies, common practices, and management decisions), or (2) from requirements needed to specify a product component. Derived requirements can also arise during analysis and design of components of the product or system. (See "product requirements.")
functional architecture	The hierarchical arrangement of functions, their internal and external (external to the aggregation itself) functional interfaces and external physical interfaces, their respective functional and performance requirements, and their design constraints.
life-cycle model	A partitioning of the life of a product into phases that guide the project from identifying customer needs through product retirement.
Non-technical requirements	Contractual provisions, commitments, conditions, and terms that affect how products or services are to be acquired. Examples include products to be delivered, data rights for delivered commercial off-the-shelf (COTS) non-developmental items (NDIs), delivery dates, and milestones with exit criteria. Other non-technical requirements include training requirements, site requirements, and deployment schedules.
product-component requirements	Product-component requirements provide a complete specification of a product component, including fit, form, function, performance, and any other requirement.
product requirements	A refinement of the customer requirements into the developers' language, making implicit requirements into explicit derived requirements. (See "product-component requirements" and "derived requirements.") The developer uses the product requirements to guide the design and building of the product.
Requirement	(1) A condition or capability needed by a user to solve a problem or achieve an objective. (2) A condition or capability that must be met or possessed by a product or product component to satisfy a contract, standard, specification, or other formally imposed documents. (3) A documented representation of a condition or capability as in (1) or (2). [IEEE 610.12-1990]
requirements analysis	The determination of product-specific performance and functional characteristics based on analyses of customer needs, expectations, and constraints; operational concept; projected utilization environments for people, products, and processes; and measures of effectiveness.
requirements management	The management of all requirements received by or generated by the project, including both technical and non-technical requirements as well as those requirements levied on the project by the organization.
risk analysis	The evaluation, classification, and prioritization of risks.
risk identification	An organized, thorough approach to seek out probable or realistic risks in achieving objectives.
risk management	An organized, analytic process to identify what might cause harm or loss (identify risks), assess and quantify the identified risks, and to develop and, if needed, implement an appropriate approach to prevent or handle risk causes that could result in significant harm or loss.
risk management strategy	An organized, technical approach to identify what might cause harm or loss (identify risks), assess and quantify the identified risks, and to develop and if needed implement an appropriate approach to prevent or handle risk causes that could result in significant harm or loss. Typically, risk management is performed for project, organization, or product-developing organizational units.

technical requirements	Properties (attributes) of products or services to be acquired or developed.
work breakdown structure	An arrangement of work elements and their relationship to each other and to the end product.
Customer	A "customer" is the party (individual, project, or organization) responsible for accepting the product or for authorizing payment. The customer is external to the project, but not necessarily external to the organization. The customer may be a higher level project. Customers are a subset of stakeholders. [FM114.HDA102.HDB103.T101]
Stakeholder	A "stakeholder" is a group or individual that is affected by or in some way accountable for the outcome of an undertaking. Stakeholders may include project members, suppliers, customers, end users, and others. [FM114.HDA102.HDB104.T101]
Relevant Stakeholder	The term "relevant stakeholder" is used to designate a stakeholder that is identified for involvement in specified activities and is included in an appropriate plan. (See the Plan Stakeholder Involvement specific practice in the Project Planning process area and the Identify and Involve Relevant Stakeholders generic practice.) [FM114.HDA102.HDB105.T101]
Verification	Although "verification" and "validation" at first seem quite similar in CMMI models, on closer inspection you can see that each addresses different issues. Verification confirms that work products properly reflect the requirements specified for them. In other words, verification ensures that "you built it right." [FM114.HDA102.HDB121.T101]
Validation	Validation confirms that the product, as provided, will fulfill its intended use. In other words, validation ensures that "you built the right thing." [FM114.HDA102.HDB122.T101]
Product Life Cycle	A "product life cycle" is the period of time, consisting of phases, that begins when a product is conceived and ends when the product is no longer available for use. Since an organization may be producing multiple products for multiple customers, one description of a product life cycle may not be adequate. Therefore, the organization may define a set of approved product life-cycle models. These models are typically found in published literature and are likely to be tailored for use in an organization. [FM114.HDA103.HDB111.T101] A product life cycle could consist of the following phases: (1) concept/vision, (2) feasibility, (3) design/development, (4) production, and (5) phase out. [FM114.HDA103.HDB111.T102]
Document	A "document" is a collection of data, regardless of the medium on which it is recorded, that generally has permanence and can be read by humans or machines. So, documents include both paper and electronic documents. [FM114.HDA103.HDB114.T101]
Architecture roadmap	Document visualising the prediction of the future: it shows external trends and/or internal opportunities over time of the architecture.
Assignment	Document used to formally start a project.
ATS	(= Acceptance Test Specification) Contains test cases that test the functional behaviour of the system (hardware + software)
Business Clock	Management tool for structuring and synchronizing the events and deliverables of the Planning processes can be developed and produced efficiently and effectively.
Com. Concept	(= Communication Concept) Communication Strategy, i.e. what we want to achieve and how we will achieve it. Visualizations of concepts proposed with a specification of communication items to be used.
Consumer	Person who acquires goods or services for direct use or ownership rather than for resale or use in production.
Contract Book	Document describing the agreement between project team and top-level owner on project scope, specs, budget, planning, quality and resources.
CRS	(=customer requirements specification) describes the requirements for a new product platform in user terminology according to the

	commercial roadmap, market requirements and the functionality, including regional diversity. It also describes the user profiles and user interface.
Customer	Person who buys goods or services
Design roadmap	Document visualizing the prediction of the future: it shows external trends and/or internal opportunities over time of the design.
F/F roadmap	(=Function / Feature roadmap) Document visualizing the prediction of the future: it shows external trends and/or internal opportunities over time of the functions and features in products.
FMS	(= functional modules specification) description of functions and their interactions. Also includes HSI (= hardware software interface), which specifies all protocols offered by the hardware that define the interface between hardware and software.
FRS	(= Functional Requirements Specification) Specifies all functional and non-functional requirements, external interfaces and design constraints of the software. The software aspects described in other requirements specifications must also be included.
HSI	(= Hardware Software Interface), which specifies all protocols offered by the hardware that define the interface between hardware and software.
IDB	(= Industrial Design Brief) A compilation of the requirements listed in the Assignment Document translated in terms of Industrial Design with additional inputs generated using High Design tools (Strategy Intent Mapping, Visual Mapping, New Attractive Qualities etc.)
LTPP	(= Long-Term Product Plan) Document describing the product families (a.o. target groups, product requirements, product positioning) that should be introduced in the market within the next 4 years. It is an input for A&SD and Technology programming.
Macro Plan	Document that sums all projects within a category (e.g. Product Realization) and key characteristics: target budget and milestones, allocation, priority.
Marketing Plan	Document, issued by the regions, used to guide execution and follow-up of introducing of a range of products in a market.
Medium-Term Product Plan	Document describing the target product families that will be introduced in the market in the next 18 months, a.o. top-level specifications, turnover per region and market introduction dates. It forms a formal contract between BCU and regions.
Mission	Reflects the task, the "raison d'être" of an organization.
Operations Plan	Document referring to the LTPP and MTPP, and containing the budget split into and the macro plans for Product Realisation, A&SD and TKHG projects
P. Mkt. Plan	(= Product Marketing Plan) Description of a new product (family) in terms of positioning, target consumer segment(s), timing and communication deliverables.
PFS1	(= Product Family Structure format 1) A high-level document, describing commercial diversity vs. functional modules.
Product Platform	A set of implemented, pre-integrated subsystems that form a common structure from which a stream of derivative products
Prototype:	In this document this term is used for a more robust representation which works in the same way as the product will work. It may be an early production model.
Reference Architecture	A top level partitioning of the functionality of a product family, and a set of interfaces between the subsystems and with the environment, and the guidelines and constraints governing the design and the application of the subsystems.
Responsible	Person who performs the task, takes the initiative, manages and organizes the activity, and reports.
Roadmap	Document visualizing the prediction of the future: it shows external trends and/or internal opportunities over time.

Scenario Descriptive narrative of a plausible projection on how the environment of a business may evolve.

SH190 (Sheet 190) Product Performance Specification. A standard TPD document described in UAT-0373

Simulation: Is a representation of the UI, often on a computer, which shows the dynamic aspects of the User Interface. As part of the UI Specification it will exactly convey the desired "Look and Feel" of the UI, but it need not be complete; it may for example not include every dialogue.

Standard Design The physical realisation of a subsystem, which complies with one or more Reference Architecture(s) and is designed for re-use.

Strategic Option Claim to (dis-) embark on a business, product or technology.

Strategy A high-level plan of action for reaching a number of goals. It serves as a guideline in decision-making and problem solving.

SysRS (= system requirements specification) describes the system architecture, specifying the system components and their interaction to satisfy the requirements given in PFS1. Also specified is the allocation of the system requirements to software and hardware, including the interconnectivity with other equipment (e.g. P50, IEEE1394, etc.)

Technology roadmap Document visualising the prediction of the future: it shows external trends and/or internal opportunities over time of the technology used.

Top-level owner Person who represents BCU management, who has the authority to start or stop a project. Also: project principal.

Trade The customers that buy from Philips and sell goods to others.

UIO (= User Interface Outline) specifies selected "Look and Feel", details of user control devices and types of feedback mechanisms. Also incorporated are artist' impressions, sketches and first drawings.

UIS (= User Interface Specification) Specifies all interactions between the users and the products and shows the UI "Look and Feel", behaviour and dynamics.

URS (= User Requirements Specification) A document containing information on the users, their tasks and the context of use upon which design decisions are based and the user-centered goals and quality criteria that will be used in evaluating them. The URS, which may be included as part of the Commercial or Customer Requirements Specification, covers User Descriptions, Context of Use (environmental and social/business aspects) and Task Descriptions.

User Interface (UI): All attributes of a product experienced by a user when using the product. All user groups who will use the product for different purposes in different environments will be, e.g. a salesman demonstrating the product in a shop, the end user at home, and a service engineer in the workshop.

User-centred evaluation criteria: The User-centered goals developed during Assignment Preparation are expanded into a set of User-centered evaluation criteria. These specify how y the achievement of the goal will be tested and measured.

User-centred goals: User-centered goals are developed during Assignment Preparation to define how the product will delight users, based on the aims of the product. They will include goals on the attractiveness and emotional impact of the product as well as goals about usability issues e.g. ease of use, learn ability, and appropriateness for the users' tasks.

- Interaction Description (detailed specification of the operating procedures)
- Specification for all product displays and other feedback to the user
- Specification for all User control actions
- UI simulation (to show UI "Look and Feel", behavior and dynamics)

Appendix D

Abbreviations

!394	A connectivity standard
802.	A connectivity standard
A&SD	Architecture & Standard Design
A/V	Audio / Video
AD	Architecture Defined milestone
ADOC	A certain HW platform
AOP	Annual Operations Plan
APD	Additional Product Documentation
AR	Architecture Release
AS	Architecture Start milestone
ATL	Above The Line
BBSC	Business Balanced Score Card
BCT	Business Creation Team
BCU	Business Creation Unit
BEST	Business Excellence through Speed and Teamwork
BMC	Basic Management Control
BoM	Bill of Material
BPT	Business Planning Team
BTL	Below The Line
C&B	Compensation and Benefits
CAD	Computer Aided Design Capabilities
CCB	Change Control Board
CCC	Customer Care Centre
CDS	Component Data sheet
CEBIT	(Exhibition)
CEDIA	Custom Electronic Design and Installation Industry (Exhibition)
CEO	Chief Executive Officer
CES	International Consumer Electronics Show (Exhibition)
CFT	Centre for Manufacturing Technology
CHS	Chassis Specifications
CMI	Consumer Market Intelligence
CMM	Capability Maturity Model
CMMI-SE/SW	Capability Maturity Model Integrated for Systems Engineering and Software Engineering
CMO	Chief Marketing Officer
CR	Commercial release milestone
CR	Change Request
CROT	Commercial Release On Time
CROV	Commercial Release On Volume
CRS	Commercial Requirements Specification
CRT	Cathode Ray Tube
CS	Concept Start milestone
CSOT	Concept Start On Time
CTO	Chief Technology Officer
CY	Current Year
DCT	Document Control Table
DfA	Design for Assembly
DfL	Design for Logistics
DfP	Design for Processability
DMM	Development Managers Meeting
DOE	Design Of Experiments
DVD+RW	Digital Video Disc + ReWriteable Function
DR	Design Release milestone
EFQM	European Foundation for Quality Management
EMC	Electro magnetic compatibility

EPR	Economic Profit Realised
F&A	Finance and Accounting
FCP	Factory Cost Price
FCR	Field Call Rate
FIL	Finance and administration, Information technology, and Logistics
FMEA	Failure Mode and Effect Analysis
FMS	Function/Module Specification
FOR	Fall Off Rate
FRS	Functional Requirements Specification
FTV	Flat TV
GCCB	Global Change Control Board
GCCB	Global product platform CCB
GDC	Global Development Centre (e.g. Brugge)
G-SysRS	Generic System Requirements Specifications
HDD	A connectivity standard
HEF	a certain range of HW components (e.g. HEF 4074)
HQA	HeadQuarter Audit
HR	Human Resource
HRM	Human Resource Management
HSI	Hardware Software Interface
HW	Hardware
IC	Integrated Circuit
IDEAL	Initiating, Diagnosing, Establishing, Acting, Learning
IDS	Interface Data Sheet
IFA	Internationale Funk Ausstellung (Exhibition)
IFO	Income from Operations
IP	Intellectual Property
IPR	Intellectual Property Rights
IPPD	Integrated Product and Process Development
IS	Integration Start
KH	Know-How
LCD	Liquid Cristal Display
LD	Launch Date
LE	Launch Evaluation
LR	Launch Release
LSB	Large Signal Board
LSDB	Lightning Stroke Data Base
LSP	Large Signal Panel
LTPP	Long-Term Product Plan
MDBI	A certain HW for audio
MECH	Mechanical ware
MEDIC	Measure and Map, Explore and Evaluate, Define and Describe, Implement and Improve, Control and Conform
MEOST	Multiple Environment Over Stress Test
MG-R	Mid Global Re-engineered (software platform)
MPATH	Market, Product requirement, Architecture, Technology and Human capability
MPR	Mass Production Release
MTBF	Mean Time Between Failures
MTPP	Medium-Term Product Plan
NOAC	Next Operation As Customer
NPV	Net Present Value
NPV	New Product Value
NSO	National Sales Organization
OAM&P	Region America & Pacific
OEM	Original Equipment Manufacturer
OPS	Operations Planning
OTC	A certain HW platform
OTL	On The Line
PBE	Philips Business Excellence

PCB	Printed Circuit Board
PCBA	PCB Assembled
PCE	Philips Consumer Electronics
PCMCIA	A connectivity standard
PCP	Product Creation Process
PD	Product Division
PD	Philips Design
PDM	Product Data Management
PDSL	Philips Digital Systems Lab
PRLE	Philips Research Lab Eindhoven
SFJ	Building on Strijp complex
PFS	Product Family Structure
PMC	Product / Market Combination
POS	Point-Of-Sale
POS	Philips Optical Storage
PPC	Product Platform Contract milestone
PPM	Parts Per Million
PPP	Product Policy Platform
PPR	Product Platform Release milestone
PR	Problem Report or Public Relations
PR/CR	Problem Report/Change Request
PRP	Product Realization Project
PRS	Product Range Start milestone
PRSOT	Product Range Start On Time
PS&P	Product Strategy and Planning
PST	Process Survey Tool
PSC-Bangalore	Philips Semi-Conductors Bangalore
P-SysRS	Product specific System Requirements Specifications
PTV	Projection TeleVision
QA	Quality Assurance
QFD	Quality Function Deployment
QIT	Quality Improvement Team
R&D	Research and Development
RM	Requirements Management
ROI	Return On Investments
RONA	Return On Net Assets
S-ATA	A connectivity standard
SBMT	Supply Base Management Team
SCCB	Subsystem (or standard design) Change Control Board
SCM	Supply Chain Management
SCORE	Strategic Core (process) Outside-in (looking) Recurring EPR based strategy planning
SD	Standard Design
SD-C	Standard Design – Contract
SD-CS	Standard Design – Concept Start
SD-DR	Standard Design – Design Release
SDM	Software Development Manual
SDP	Software Development Plan
SD-VR	Standard Design – Volume Release
SEI	Software Engineering Institute
SPI	Software Process Improvement
SPO	Software Project Office
SR	Slip Rate: the gap between expected and actual values as applied to project time and project budget
SSB	Small Signal Board
SSP	Small Signal Panel
SW	Software
SWOT	Strength, Weakness, Opportunity, and Threat
SysRS	System Requirements Specification
TIC	Total Industrial Costs

TKHG	Technology Know-How Generation
TPD	Technical Product Documentation
TPM	Total Productive Maintenance
TRACI	Task Responsibility Authority Consultancy Information
TTM	Time To Market
TvPlf	TV platform (subsystem SW)
UIO	User Interface Outline
UIS	User Interface Specification
UPI	Usability and Please of use Indicators
USB	Universal Serial Bus
USP	Unique Selling Point
VISIO	Drawing application
VCR	Video Cassette Recorder
VDR	Video Disc Recorder
VSM	Virtual Shared Memory
WBS	Work Breakdown Structure
QITs	Quality Improvement Teams
HQA	Head Quarter Audit
PST	Process Survey Tool
C&B	Compensation & Benefits
IDB	Industrial Design Brief

Appendix E

In this appendix the Product Creation Process what is followed in a BCU is described. This Research is focused on a part of this process in a BCU, namely on the Architecture & Standard Design Creation Process. Speed processes are introduced in Philips CE BCU's since 1997. Later on the processes are employed until how it is described today, see figure 4. At the end of this chapter two tools will be explained that are used to support the Philips CE primary processes.

1.3.1 Speed in General

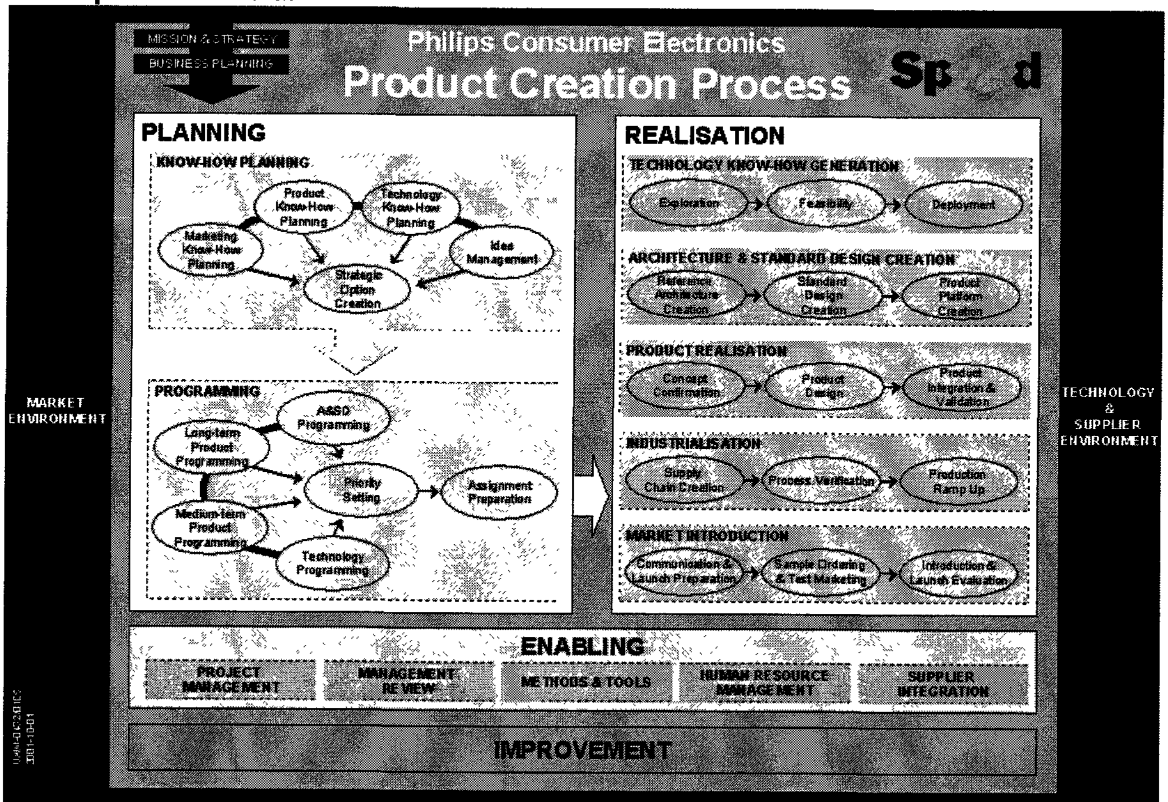


Figure 4: Product Creation Process of Philips Consumer Electronics

The Speed process model is a means to describe the various processes that take place in product creation.
The Speed model of the product creation process (PCP) consists of 2 groups of primary processes:
Planning processes, i.e., the preparatory planning of product creation activities.
Realization processes, i.e., the realization of the planned activities.

Excellence in these, however, can be achieved if also excellence is achieved in the two groups of supporting processes:
Enabling processes, i.e., common cross- PCP supportive activities.
Improvement processes, i.e. an explicit approach to improvement of all PCP activities.

These four groups are further subdivided as follows.

1.3.1.1 Group 1: Planning processes

Know How Planning

Define viable strategic options for future business success. Align with business mission and strategy. Analyze markets, technology, industry and supply chain; generate ideas based on gaps and opportunities found. Visualize trends into a top-level roadmap and detailed marketing, product requirement, and technology roadmap views. Underpin with business cases and scenario studies.

Programming

Translate strategic options into long term and medium term product plans as well as plans for future technology, architecture and common building blocks. Analyze and agree resource impact and feasibility with stakeholders.

Set priorities using resource constraints and defined business criteria. Create assignments for realization projects based on consolidated operations plan.

1.3.1.2 Group 2: Realization processes

Technology know how generation

Explore, create or obtain know how on product- and/or manufacturing process technology. Assess impact on future business in terms of applications, products and markets. Deploy the technology know-how for use in future realization projects.

Architecture and Standard Design Creation

Update, manage and create reference architectures. Create common building blocks (named within SPEED Standard Designs). Pre-integrate and evaluate the combination of a number of standard designs into a product platform as the basis for further product realization.

Product Realization

Create complete product design through use of pre-integrated product platforms and Standard Designs, through development of specific peak designs or through the use of new technology in carrier products. Confirm concept & business feasibility, perform product implementation, and integrate & validate the product against pre-defined criteria

Industrialization

Design and create the logistics chain including component suppliers, PCBA, assembly, transport and delivery. Establish process capability according product & FCR requirements.

Market introduction

Prepare and plan introduction of products to the market. Provide documentation and samples to develop the market and obtain adequate feedback. Execute the product Launch plan and evaluate market success to improve subsequent Programming and Realization processes.

1.3.1.3 Group 3: Enabling processes

Project management

Manage the trade offs between the specified performance and product costs, project costs and schedule in order to achieve optimal results; plan, monitor, and control the activities and deliverables of a project. Lead a cross-functional team, manage risks and ensure proper communication.

Management Review

Verify compliance to the Product creation process. Provide direction to process teams to enhance quality, effectiveness and efficiency of the PCP; check adherence of project progress against established plans and standards; facilitate smooth and efficient project execution.

Methods and tools

Support the efficient execution of the Product creation process with adequate methods and tools.

Human Resource Management

Provide motivated and dedicated human resource for executing the product creation process. Ensure current and future capabilities are in line with business requirements.

Supplier integration

Maximize the leverage of the capabilities of both suppliers and the BCU; deal with the in- and out sourcing of realization activities.

1.3.1.4 Group 4: Improvement processes

Ensure continuous improvement in the PCP, whenever possible guided by established improvement frameworks or reference models with their associated assessment tools and by actively using collected metrics and lessons learned from the existing way of working. [1]

Appendix F

Architecture & Standard Design Creation Processes

The main elements of the A&SD processes are:
Architecture and Standard design planning: In this process, the future direction of the business with respect to Reference Architecture and product Platforms is defined and documented in a set of roadmaps.
Reference architecture creation: In this process, the requirements of a product family are analyzed. The partitioning into subsystems, a mapping of functionality to subsystems and interfaces between the subsystems are defined and documented.
Standard Design Creation: This process covers the realization of the subsystems, more specifically the specification, development, testing and documentation of the standard designs.
Product Platform Creation: This process covers the integration and validation of a number of standard designs, from which the members of a product Family can be realized. [2]

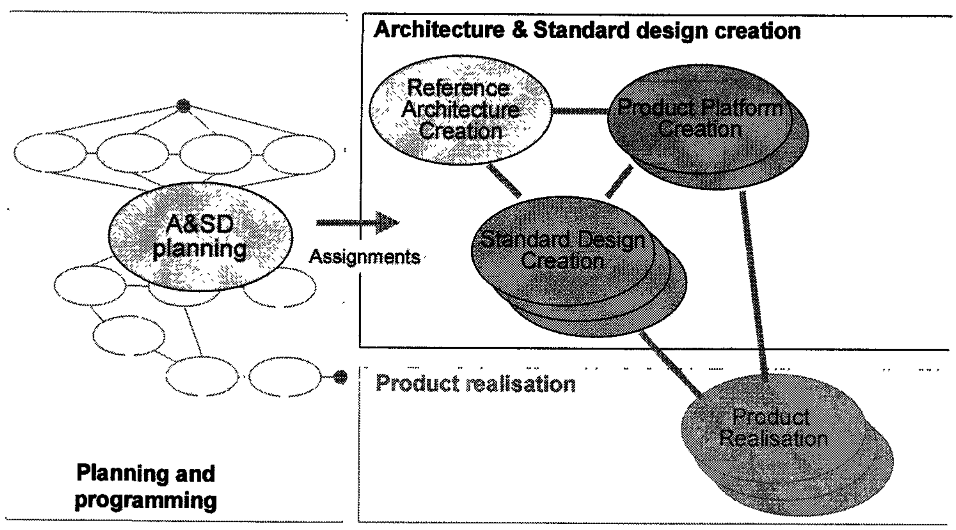
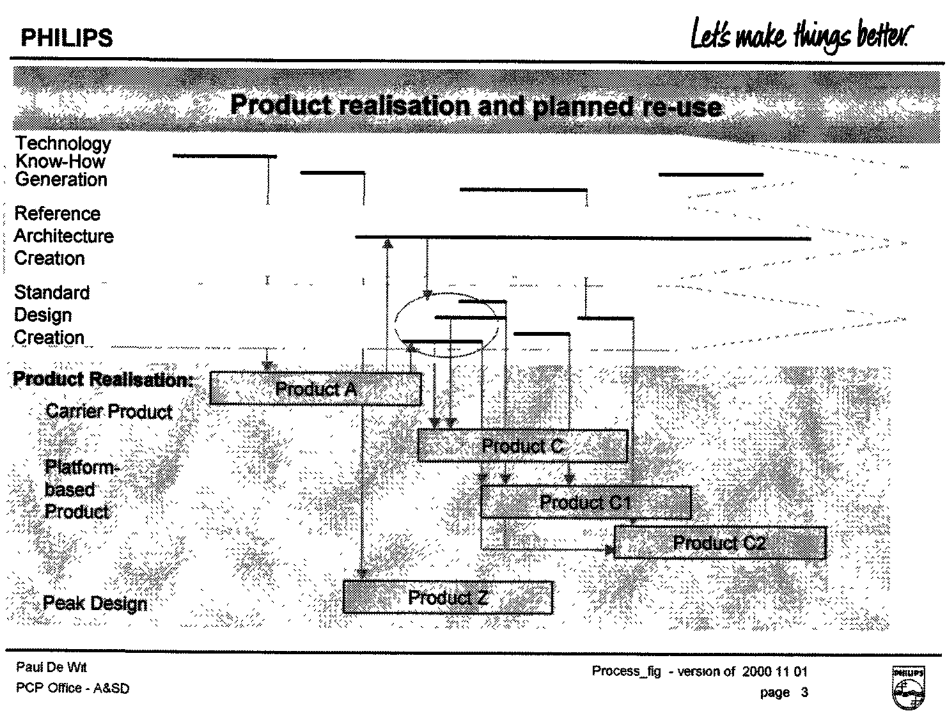


Figure 6: Architecture and Standard Design Creation Process



3.3.7 A&SD process (PCP office, Paul de Wit, 1998)

Requirements Analyses

1.Capture the LTPP & F/F roadmap
2.Analyse the LTPP & F/F roadmap
3.Define a set of key drivers
4.Define system requirements
5.Clarify domain
6.Clarify target platform lifetime
7.Discover latent customer needs
8.Perform detailed functional requirement analysis
9.Perform logical grouping of functionality
10.Allocate requirements to the functions
11.Establish a draft system requirement specification

Outline design

12.Select solutions for key design issues
13.Identify key requirements and constraints
14.Acquire analyze results of competition benchmark studies
15.Brainstorm candidate solutions
    16.Identify candidate subsystems
    17.Identify interfaces
18.Refine solutions
19.Develop hierarchical model of layered system
20.Analyse candidate solutions and perform trade off studies
    21.Analyse platform requirements
    22.Analyse design constraints
    23.Analyse risks
    24.Analyse diversity
    25.Analyse industrial process constraints
    26.Analyse price
    27.Analyse capacity constraints
    28.Analyse intellectual property/patent a/o standardization issues
    29.Analyse candidate solutions in a multidisciplinary team
30.Perform architectural decomposition at a subsequent level of detail
31.Cover design for manufacturing and logistics issues concurrently
32.Analyse key components: co-design, design-in
33.Perform iterations (SPIRAL MODEL) refine requirements.
34.Update outline design, prototype, simulation, test, verify until robust solution
35.Select solution

Develop Reference architecture

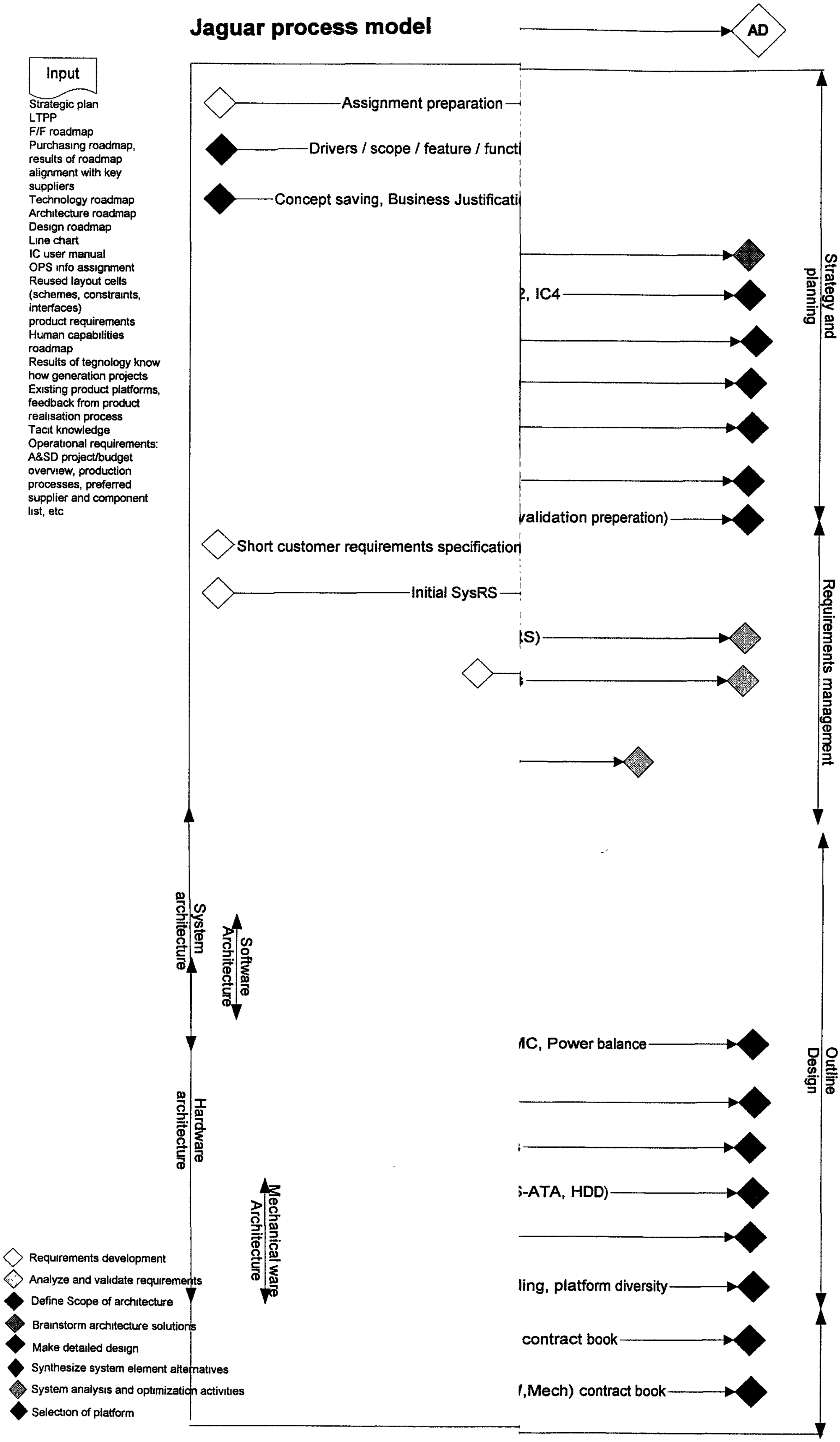
36.Define and describe the subsystems & interfaces
37.Document the candidate architectures and trade off studies that led to the final choices
38.Document diversity and product family extensions
39.Document design rules architectural guidelines and constraints
40.Baseline reference architecture and put documents under change control
41.Document the business justification
42. Prepare for management commitment for the creation of a new product platform

Appendix G

Jaguar process model

Input

Strategic plan
LTPP
F/F roadmap
Purchasing roadmap, results of roadmap alignment with key suppliers
Technology roadmap
Architecture roadmap
Design roadmap
Line chart
IC user manual
OPS info assignment
Reused layout cells (schemes, constraints, interfaces)
product requirements
Human capabilities roadmap
Results of tegnology know how generation projects
Existing product platforms, feedback from product realisation process
Tacit knowledge
Operational requirements: A&SD project/budget overview, production processes, preferred supplier and component list, etc



Output

Drivers, Market, Scope, Feature Function
Concept saving, Business Justification, NPV
Modules, layout cells, interface, space, temperature, EMC, Power balance
Top Level architecture, requirement mapping, control architecture, SW diversity strategy, tooling
Set architecture (PTV, CRT, FTV), Brackets, shielding, tooling, platform diversity
Digital connectivity (USB, I 394, 802., PCMCIA, S-ATA, HDD)
PTV (spec coverage), interfaces (HW, SW, Mech), contract book
FTV Platform status, (Spec coverage), interfaces (HW, SW, Mech), contract book
Requirements management (SysRS, FMS, CHS, FRS)
Quality plan, risk assessment, Field Call Rate (FCR)
Platform diversity mapping
Environmental requirements and status
Key component overview and status (Purchasing issues?)
Patent position/ infringement
intellectual property right (IPR) status
Industrial strategy and industrial costs IC2, IC4
Service and repair strategy
Work breakdown structure- first product platform (platform validation preparation)

Appendix H

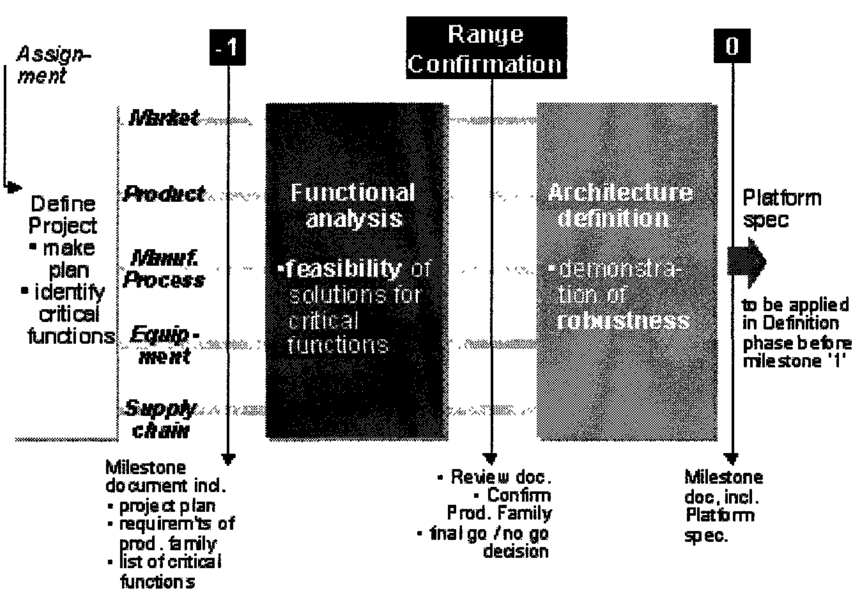
TL-5 process model

Input
The assignment is the main document. In here the goals are set for the final result. Next to this the different requirement specifications provide input.
A new lamp concept, for which the technical feasibility has been demonstrated and which has been evaluated for market attractiveness (applications, products), or
An idea for a (more of less completely) new manufacturing platform for an existing lamp concept, or
An existing product- or manufacturing platform, which needs to be improved (e.g., for cost reduction) or extended.
Most assignments are to improve the production process.

Activities
Architecture and standard design process is the same process as described in the speed documents. The process was divided in two main parts. I.e. functional analysis and architecture definition (mainly hardware).

The processes to solve the issues were different dependent of the kind of issue. In one case 3 iterations of the cycle were necessary in the other case one cycle was enough. Or solutions for one issue were made parallel and the strongest survived. For example the heating-curve of the glass is important and very complex.

Philips Lighting follows the next steps in its reference architecture creation or so called platform definition process:



Definition
The Definition phase starts with the assignment document, for which a standard template is available. In the Definition phase, the assignment is reformulated and a project plan is developed.
Specifically for platform projects, the basic steps are:

- Identify and agree the (market-/application-/supply chain-) requirements for the product family, now and in the future
- Identify and agree the range of the product family: the (possibly) required diversity of products in the family
- Translate requirements to functionality: identify the functions that are critical with respect to requirements and/or diversity
- Make high-level functional architecture, zooming in into critical functions

- For the critical functions, assess the technology and the technological options that are available; decide which will be applied and/or explored in the project
- Make a work breakdown for the project, based on the need to develop technology for implementing the critical functions

Milestone '-1'

Input of Platform Definition process at milestone '-1':

Approved milestone '-1' document, containing:

- Project plan, with committed resources and budget, including estimate of budget for building pilot equipment (if applicable)
- Platform requirement specification for the new or improved platform to be developed: customer requirements for the platform, from an application, market, supply chain and financial perspective; including identification of the targeted range of the platform
- Available technology, such as a proven lamp concept for which a platform will be developed or an existing platform that will be extended or improved in the project.
- Identification of critical functions of the platform to be developed; i.e., the areas in the platform with the highest technical risks.

The Project Manager and the team are responsible for the milestone document. This includes the project plan, ready for approval in a review meeting. The approved document is the contract between the Principal and the Project Manager (and agreed by the Management Review Team and the Project Team) which is needed for starting the execution phase of the project.

<u>*Functional analysis*</u>

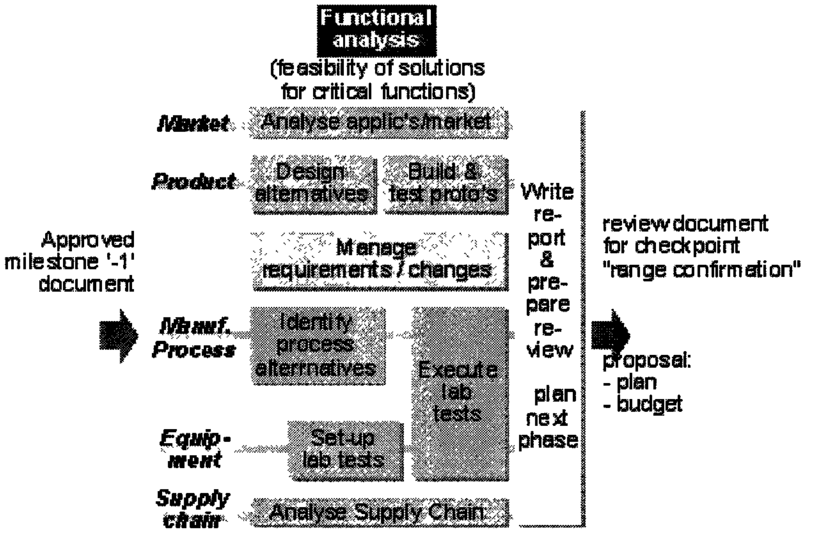
The goal of this process is to analyze the critical functions and interfaces of the platform to be developed and to show that technical solutions for these critical functions are feasible, if necessary by applying lab testing.

Input: Approved milestone '-1' document.

Activity: Analyze the critical functions and interfaces of the platform to be developed and show that technical solutions for these critical functions are feasible, if necessary by applying lab testing. This part of the process aims at resolving high risks.

A critical function is typically a technically high-risk area, for which no (sufficiently robust and/or cost-effective) solutions are available (yet).

Output: Decision document for "range confirmation": summary of feasibility results. Including plan for next phase.



Checkpoint with project review: Range Confirmation

At this point in the Platform Definition Process, it is clear whether or not (or to what extent) the requirements for the platform will be met, for example with respect to the range of products (product family) that can be derived from the platform.

Now, a project review can be organized called "range confirmation". At this review, the main decisions that have to be made are:

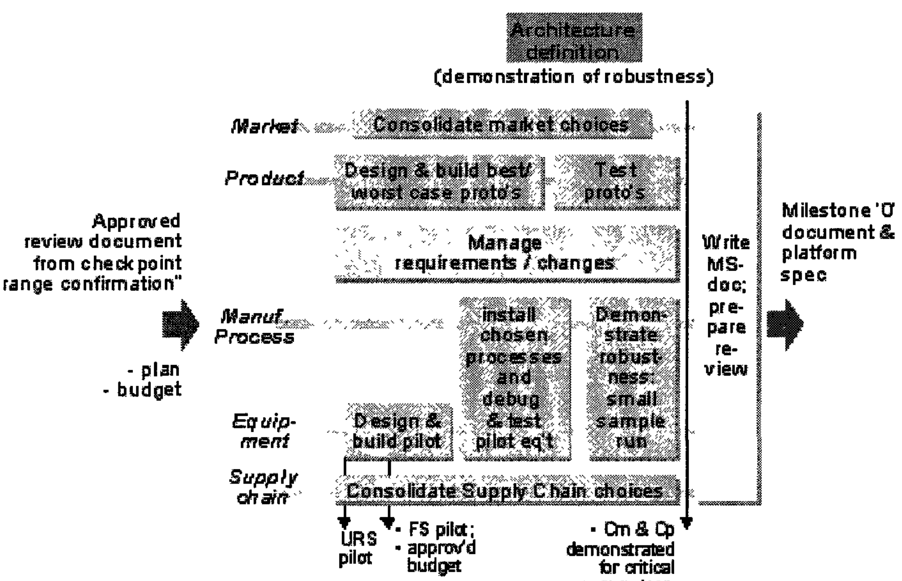
- given the technical feasibility of the critical functions, is the platform sufficiently attractive? And:
- do we agree to continue the project?

This second question is important because the next activities of the PDP might require the building of pilot equipment for which investments are required. See platform robustness.
If, for a critical function, no solutions can be found fulfilling its requirements, then a part of the possible market volume for the platform might disappear. As a result, the platform might not be economically viable any more. And, in this example, it might lead to stopping the platform project long before milestone '0' is reached. In other cases, it might lead to a redefinition of the customer requirements of the project. Another possibility might be to look for (less cost-effective) back-up solutions of the critical function.
The Project Manager and the team are responsible for the review document, ready for approval in a review meeting.

Input: Decision document for "range confirmation"
Activity: It is now clear whether or not (or to what extent) the requirements for the platform will be met, for example with respect to the range of products (product family) that can be derived from the platform. Decisions that have to be made are: given the technical feasibility of the critical functions, is the platform sufficiently attractive? And: do we agree to continue the project?
Output: Approved decision doc. for "range confirmation", with go / no go decision

Architecture Definition
The goal of this process is to demonstrate the robustness of the platform, for its agreed range of application, if necessary by executing industrially- representative pilot-testing.

Input: Approved decision doc. for "range confirmation"
Activity: Demonstrate the robustness of the platform, for its agreed range of application, if necessary by executing industrially representative pilot testing. This part of the process aims at resolving medium risks.
Output: Milestone '0' document



Milestone '0'

Output of Platform Definition process at milestone '0': Approved milestone '0'-document, containing (among other things):
-Platform specification: consolidated, documented platform architecture (of product, process, equipment):

- key product parameters identified & understood,
- key component parameters identified & understood,
- key process parameters identified & feasibility shown in industrially representative test-stand (Cp targets),
- key equipment design parameters identified & understood (Cm),
- risk management plan,

-Consolidated market data (including identification and assessment of market risks),
-Consolidated supply chain data, including supply base (key suppliers / partners; including identification and assessment of risks in the supply chain),
-Consolidated financial data (global; including sensitivity analysis).

The Project Manager and the team are responsible for the milestone document, ready for approval in a review meeting.

Input: Milestone '0' document
Activity: At milestone'0' the (global) platform is defined and approved
Part of the milestone '0' document is the platform specification.
Output: Milestone '0' document, approved by Management Review Team

Evaluation / after care

The technical output of a platform project is the platform specification, as part of the "milestone 0" - document. Part of the platform specification is:

- the chosen architecture of the platform,
- the technical solutions found for each of the critical functions of the platform and the demonstration of their capability within the chosen architecture.

Together, this knowledge is applied in Product Creation, Manufacturing Process Creation and Equipment Creation. For example, suppose for a new product platform, in the Product Creation process the platform architecture is applied for the first time. That is, for a first 'lead family of products' all the building blocks of the platform are developed in full detail up to the level that the first family of products can be released to the market. As a result, when a platform is applied for the second time, a number of building blocks, which are common for the whole application range of the platform, are already available and can thus be re-used.

Appendix I

System engineering guidebook process model [James N. Martin, 1997]

Requirement analysis activities:

1.Collect stakeholder requirements
2.Define system mission/objective
3.Define system scenarios
4.Define system boundary
5.Define environmental & design constraints
6.Define operations & support concept
7.Define measures of effectiveness
8.Define / derive functional and performance requirements
9.Validate requirements
10.Integrate requirements

Functional Analysis / allocation activities:

11.Define system states & modes
12.Define system functions
13.Define functional interfaces
14.Define performance requirements and allocate to functions
15.Analyze performance and scenarios
16.Analyze timing & resources
17.Analyze failure mode effects and criticality
18.Define fault detection & recovery behavior
19.Integrate functions

Synthesis activities:

20.Assess technology alternatives
21.Synthesize system element alternatives
22.Allocate functions to system elements
23.Allocate constraints to system elements
24.Define physical interfaces
25.Define platform and architecture
26.Refine work breakdown structure (WBS)
27.Develop life cycle techniques & procedures
28.Check requirements compliance
29.Integrate system elements
30.Select preferred design

System analysis and optimization activities:

31.Develop system models
32.Perform system effectiveness and cost effectiveness analysis
33.Risk evaluation
34.Trade studies

Requirements and architecture documentation activities:

35.Develop document approach
36.Develop detailed document outline
37.Develop text
38.Develop graphics
39.Produce document
40.Deliver document

Appendix J

Capability Maturity Model Integration v:1.1 (SEI, 2002)

The CMMI includes a common set of process areas which form the core of an integrated capability model that integrates process improvement guidance for systems engineering, software engineering, and Integrated Product and Process Development (IPPD). The model provides an integrated approach to reducing the redundancy and complexity resulting from the use of separate, multiple capability maturity models (CMMs). The CMMI products should improve the efficiency of and the return on investment for process improvement. The resulting integrated capability models will be tailorable to an organization's mission and business objectives.

The following activities are described:

Requirements Development

1.Develop Customer Requirements
2.Elicit Needs
3.Develop the Customer Requirements
4.Develop Product Requirements
5.Establish Product and Product-Component Requirements
6.Allocate Product-Component Requirements
7.Identify Interface Requirements
8.Analyze and Validate Requirements
9.Establish Operational Concepts and Scenarios
10.Establish a Definition of Required Functionality
11.Analyze Requirements
12.Analyze Requirements to Achieve Balance
13.Validate Requirements with Comprehensive Methods
Institutionalize a Defined Process (**)

Technical Solution

14.Select Product-Component Solutions
15.Develop Detailed Alternative Solutions and Selection Criteria
16.Evolve Operational Concepts and Scenarios
17.Select Product-Component Solutions
18.Develop the Design
19.Design the Product or Product Component
20.Establish a Technical Data Package
21.Design Interfaces Using Criteria
22.Perform Make, Buy, or Reuse Analyses
23.Implement the Product Design
24.Implement the Design
25.Develop Product Support Documentation
Institutionalize a Defined Process (**)

Product integration

26.Prepare for Product Integration
27.Determine Integration Sequence
28.Establish the Product Integration Environment
29.Establish Product Integration Procedures and Criteria
30.Ensure Interface Compatibility
31.Review Interface Descriptions for Completeness
32.Manage Interfaces
33.Assemble Product Components and Deliver the Product
34.Confirm Readiness of Product Components for Integration
35.Assemble Product Components
36.Evaluate Assembled Product Components
37.Package and Deliver the Product or Product Component
Institutionalize a Defined Process (**)

Verification

38.Prepare for Verification
39.Select Work Products for Verification
40.Establish the Verification Environment
41.Establish Verification Procedures and Criteria
42.Perform Peer Reviews

43.Prepare for Peer Reviews
44.Conduct Peer Reviews
45.Analyze Peer Review Data
46.Verify Selected Work Products
47.Perform Verification
48.Analyze Verification Results and Identify Corrective Action
Institutionalize a Defined Process (**)

(**) First establish and maintain the description of a defined requirements management process. Secondly, collect work products, measures, measurement results, and improvement information derived from planning and performing the requirements management process to support the future use and improvement of the organization's processes and process assets.

- Establish an Organizational Policy
- Establish a Defined Process
- Plan the Process
- Provide Resources
- Assign Responsibility
- Train People
- Manage Configurations
- Identify and Involve Relevant Stakeholders
- Monitor and Control the Process
- Collect Improvement Information
- Objectively Evaluate Adherence

Review Status with Higher Level Management