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Managing complex development projects

– using the system anatomy

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Abstract -This paper investigates the use of a construct called the system anatomy for planning and controlling projects developing complex systems. The anatomy shows, in a compact form, the most crucial dependencies in the system from the perspective of how it 'comes-to-life', hence the concept of an 'anatomy'. The key point in using the anatomy for project planning is to develop and verify the system in the same order as it 'comes-to-life'. The project plan in made up in three steps. The first step is to define the anatomy itself. This is followed by the grouping of functions into verifiable integration steps called increments. Finally, regular time and resource plans are made for each increment. Thus, the planning can be characterized as an integration driven procedure. This approach has been used extensively at Ericsson, a leading manufacturer of telecommunication systems world wide. It has proven to be very successful, especially in terms of promoting communication and developing a shared understanding about the project.

I INTRODUCTION

The scope of this paper is the management of complex system development projects, such as the development of 3rd generation mobile systems. Managing these kinds of projects means coping with an almost endless amount of technical, market and organizational interdependencies that most often require mutual adjustment across many types of technical and organizational boundaries [2]. However, the management of these projects is also challenged by an ever-increasing pace of technical development, new standards, and changing customer demands; which necessitate a flexibility to add new technical solutions or functions during the development process. Consequently, new factors and interdependencies arise throughout the project that must be dealt with dynamically to meet both fixed and emerging targets [2].

Many of the project management methods and tools of today are based on the assumption that projects can be thoroughly planned and that change of any kind is something you should avoid. When managing complex system development, the most common approach [10, 13] is characterized by an assumption that complexity can be reduced by breaking it down into pieces, and uncertainty can be reduced by rigorous planning. This approach often fails to clarify the crucial dependencies between system functions, since the 'breaking down' approach is top-down, and thus does not show how the system actually works. As a consequence, the actors involved in the system development are only provided with their own small pieces and plan of action, knowing little about the system as a whole or how their system part fits in. The price we pay using this approach according to Senge is that we can not se the consequences of our actions; we lose our intrinsic sense of connection to a larger whole, and thus fail to see "*the big picture*" [17]. When managing large projects, there is still a belief that project managers should focus on managing cost, time, scope, and quality under the implementation phase. Very little discussions center on whether or not the project's business case has been enhanced, because of new business opportunities. So it is not uncommon to read reports in the press on cost and time overruns experienced on large projects [8].

Consequently, there is a need for an easy-to-understand method supplementing the common tools of managing projects. The purpose of such a method is to help the project managers provide a shared understanding of the developed effort; and allow the involved actors to discuss the effects of changes and make decisions quickly. The aim of this paper is to present an approach that has been used successfully when managing complex system development projects at the Swedish telecommunication-supplier Ericsson. The approach is performed bottom-up instead of top-down as in the traditionally used *work breakdown structure*. Further, it provides a one page picture, called the *anatomy,* of the system to be developed. This picture is the heart of the suggested approach; and is used to create a shared understanding of the system solution, plan the project, and provide the means for an efficient follow-up of the status of the subprojects included in the project. The goal is to develop the system in the same order as it starts up, in order to start integrate and test the system as early as possible, thus it can be characterized as an integration-driven procedure. It is an approach for the total project management team to obtain control of complex projects.

The paper is outlined as follows. First, we describe the research design. Then, we describe the anatomy construct; followed by a section of how the anatomy is used for project planning in three steps. This is followed by a case study of one of the first projects to use the approach. In section VI, we discuss how the approach relates to traditional planning as well as how it is used as a tool to provide a shared understanding. Further, some of the advantaged and disadvantages of the approach are discussed. Finally, the paper ends with the conclusion, highlighting the benefits of using the anatomy approach.

II RESEARCH DESIGN

This research effort is exploratory in nature and is based on case studies. The use of qualitative methods is appropriate to study the system development process in its real context, especially in those situations in which practice precedes theory. [19] The empirical data is not only collected from the case study described in the paper, but also from experiences of several integration driven projects at Ericsson.

The author Taxén has been active in providing tool support for these types of projects at Ericsson while simultaneously doing research in this area [15]. The co-author, Klasson, has been project manager at Ericsson, and was participating in the project described. This means that the research can, at least in part, be classified as action research [3]. Thus, the empirical data is a mixture of personal experiences from many projects and a deeper study of one particular project. Based on this we claim that the effects discussed are valid in a broader context than the described project.

III THE ANATOMY CONSTRUCT

In order to explain the anatomy we will use the Otto motor as an example (modified after Anderstedt et al. [1]) and a processor in a telecom system. The examples are simplistic compared to the telecommunication systems the anatomy was developed to support, but it suits the purpose of this paper to describe the approach of the anatomy. Fig. 6, however, provides an example of the anatomy from a more complex project where it has been used in.

In the industrial practice a common model of a system is the product structure, which shows which parts a product consists of. In Fig. 1, a product structure of the Otto motor is shown:

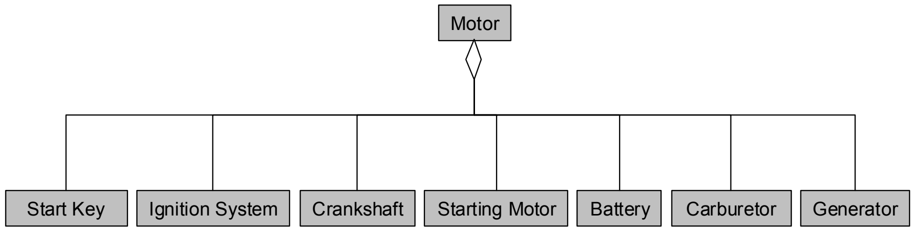

Fig. 1 Product structure (Otto engine)

The product structure is used to describe the product and manage it during development and maintenance. However, when breaking down the product structure in system development projects, i.e. performing the work breakdown structure, it becomes very complex due to the number of elements. The number of elements in the product structure makes it difficult to capture the crucial dependencies between the parts. In the development of complex systems, the network diagrams based on the WBS tends to become large and complex [1] and thus do not provide the "big picture". This is supported by Taxén [15], who in a study of complex system development projects found that there was not a lack of detailed specifications of the different parts of the system to be developed. Rather, there are literally thousands and thousands of specifications, but there is a lack of a comprehensive view of the system to be developed. Thus, in complex system development, this type of structure is necessary but not sufficient.

The anatomy construct is an attempt to model a system from the perspective of what it offers the end-user. In Fig. 2, an anatomy of the Otto engine is shown. The anatomy should be read from the bottom up. It shows the functional dependencies in the system from start-up to a fully operational system. Thus, the boxes in the figure should be read as functions or capabilities. An arrow between the boxes indicates a dependency. The mind setting behind the anatomy is how to "breath-life-into-a-system". In order to start the engine a start mechanism and a power source is needed. This could, for example, be provided by a start key and a battery. This enables the starting motor functionality; that is, providing torque to the crankshaft. The torque, start and power functionalities enable the ignition functionality, which together with the carburetor functionality enable the motor functionality. This in turn enables other functionalities until the complete car functionality is available. As can be seen, the anatomy is completely different from the product structure.

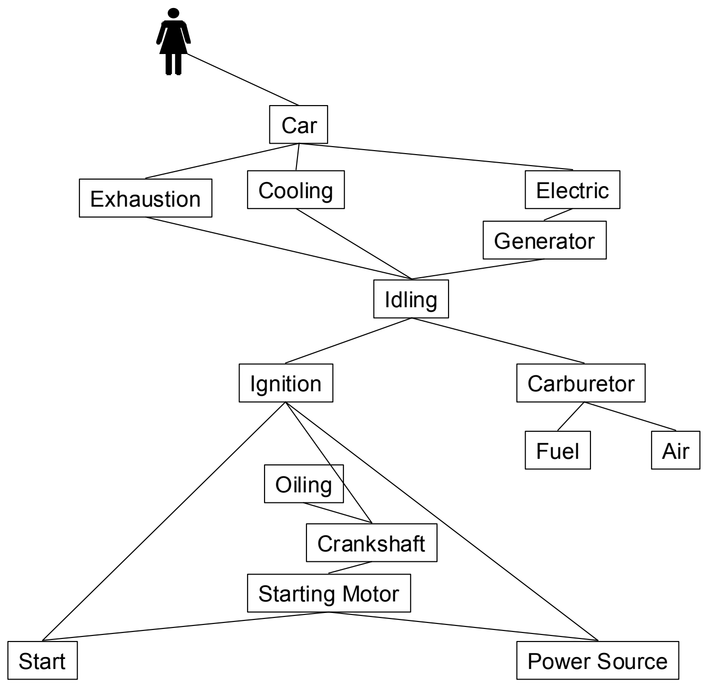

Fig. 2 System anatomy (Otto engine)

The way a system is modeled will bring about a certain 'mind-set' of how the actors 'see' the system. This will frame what actions are considered feasible, what support systems and method to use, what design rules to follow, etc. The product structure model emphasizes descriptive and management aspects of the system. The anatomy, on the other hand, emphasizes dependencies in the system. Thus, the introduction of the anatomy in the development practice necessitates a change in mind-set.

In a companion paper a theoretical grounding of the anatomy is given [16]. We propose that the anatomy can be apprehended as a particular type of *affordance*. This concept was introduced by Gibson [6] to indicate action possibilities available to an organism in its environment. For example, a chair would signify the affordance 'sit-ability' for humans. In this interpretation, the anatomy can be seen as indicating possible actions for different groups of actors such as systems architects, designers, project managers, test managers, etc. During the definition of the anatomy, these actors gradually become aware of what actions they may take and whether these are in conflict with each other. What matters is that the anatomy, like any affordance, provides these insights in a direct and immediate way which is easily comprehended by all actors.

IV THE ANATOMY APPROACH AS AN INSTRUMENT FOR PROJECT PLANNING

The key point in using the anatomy as basis for project planning is to develop and test the system in the same order as the system 'comes alive'. Based on this principle, the project plan in defined in three steps: *anatomy definition, increment planning* and *integration planning*. These steps should not be seen as strictly sequential; rather they should be seen as different foci in the coordination of the development task. Often, they are iterated depending on changed circumstances and unforeseen events occurring during the project. In the following sections we will describe the principles of the planning process using a simplified example from the Ericsson practice: the development of a processor in a telecom system.

A Anatomy definition

The purpose of the first step is to establish a shared architectural view of the system in the form of an anatomy. All the involved actors should have the same general image of what should be achieved rather than a two-hundred page specification in which one is left to create their own interpretation. The image may be more or less correct; nevertheless, actors always work and solve their part of the problem on the basis of the image they have.

The anatomy should show the major parts of the system from an integration and testability perspective. This is achieved by focusing on the necessary functions and their dependencies to start the system. The implementation of each function is subdued at this stage. For example, in the anatomy of the Otto motor in Fig. 2 it is irrelevant how the ignition system provides the function ignition.

The anatomy is created in a process where a group of actors, mainly system architects and experts, meet and discuss which functions are necessary in order to build-up the system from zero to full-system functionality. The mindset at these meetings should be: "*if you 'power-on' what happen then and then.*" The question is repeated until you reach the end functionality. Thus, this approach focuses on building up, instead of breaking down [1].

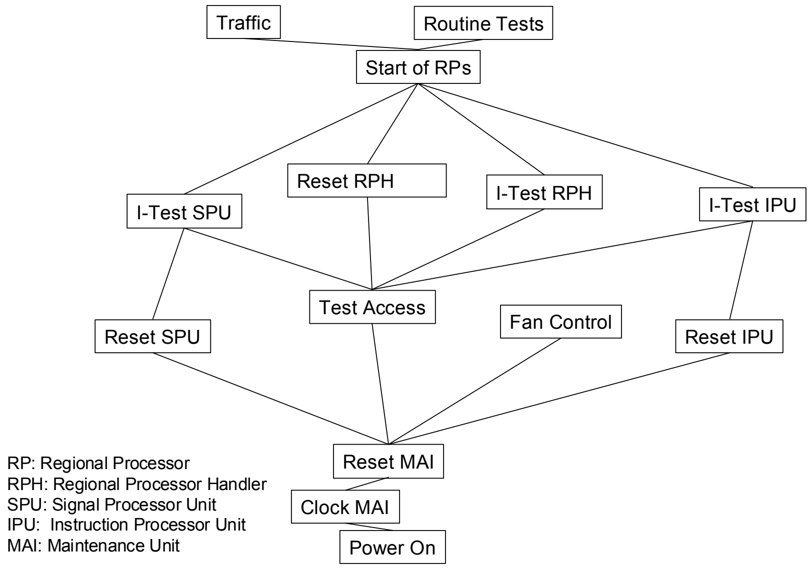

Fig. 3 The anatomy of a processor in a telecom system

The anatomy created is iterated several times until agreed upon throughout the group. The leader of this activity has to keep in mind that the anatomy can never be complete, but it must be correct in its main features. In essence, the anatomy will provide a picture of how the final system work, which functions it consist of, which functions that are related to each other and which are not. Equally important, in this process a shared image of the system is created in the minds of the actors.

The anatomy is to a certain extent re-usable. Although different projects may emphasize different aspects, they can start from the same anatomy. For example, the anatomy of the Otto engine in Fig 2 differs very little from the first Otto engine. The implementation of all of the parts, however, differs quite a lot.

B Increment planning

In the second step, the purpose is to find a shared view of how to implement the system. This is done in the form of an increment plan. The functions are grouped into integration steps — increments — in such a way that the resulting sub-system after each added increment can be verified. In line with the metaphor of the anatomy, this could be apprehended as defining the major ‘organs’ in the system. As a matter of fact, this second step is called “Organic Integration Planning” at Ericsson.

The intention is to parallelize design and testing as much as possible. The increment plan describes in what order increments need to be completed to ensure smooth progress. The structure of the plan is determined by a number of circumstances such as: the system architecture, available resources, customer feedback, complicated or simple functions, geographical proximity between resources, functions that can be tested jointly, etc. [1]. In Fig. 3, a possible increment plan of the processor is shown.

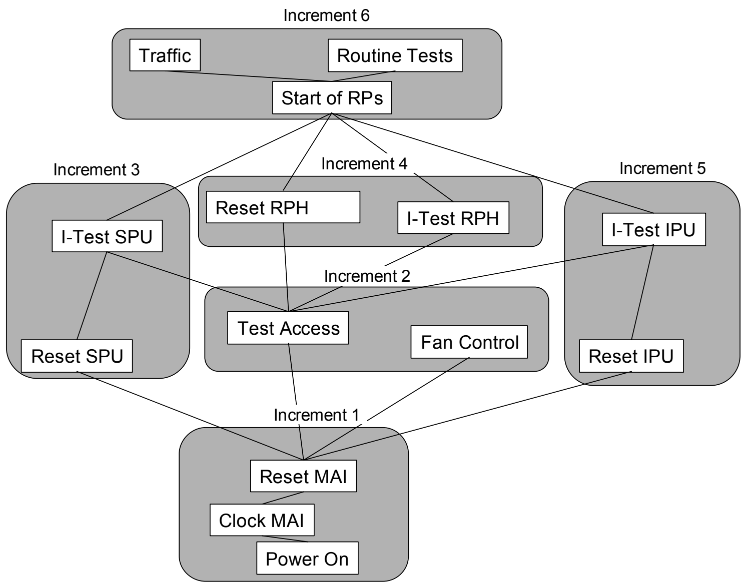

Fig. 4 Increment plan of the processor

The increment plan can be regarded as an integration plan (see next section) without any dates. It shows what can be done in parallel. For example, increments 2, 3 and 5 can be started independently of each other. However, they cannot be verified until increment 1 is ready. Moreover, increment 3 and 5 are dependent on increment 2. The increment plan also shows important 'collection' points where several increments must be ready in order to proceed further. For example, increment 6 cannot be verified before increments 3, 4 and 5 are ready. Nonetheless, this does not necessarily mean that increment 6 cannot be started before this happens. As a matter of fact, the intent is to start with the different increments as early as possible in order to shorten the development time.

C Integration planning

In the third step, the purpose is to establish an integration plan based on the anatomy and the increment plan. This means that subprojects are defined, resources are assigned and dates for deliveries of the increments are settled. For each increment, traditional time and resource plans are made.

The integration plan describe what is delivered, from whom and when. It also clarifies the receiver for each internal delivery. Thus, it focuses on the dependencies between subprojects. The impacts of a delay are clearly visible since all the internal deliveries are related to the delivery of the final system to the customer. Thus, it provides the project with early warnings of delays, and gives the project management ample time to take corrective actions.

In order to simplify the complexity when many increments are involved, internal functions in an increment may be subdued in the integration plan. Often, this plan is 'tilted' compared to the anatomy in order to be aligned with a time line, see Fig. 5.

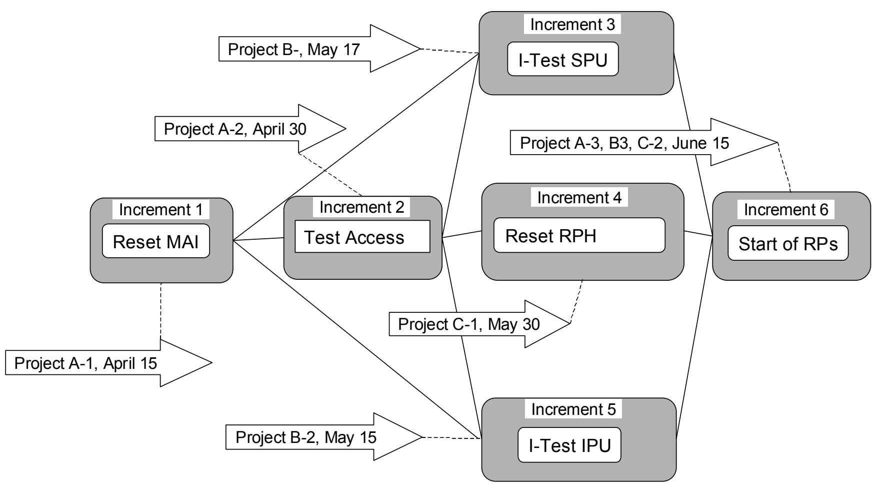

Fig. 5 Integration plan of the processor

During the project, the state of each increment may be associated with traffic-light colors such as Green – On Plan, Yellow – Warning, Red – Off Track. The integration plan is one of the main documents used by designers, project managers. It is also used in the interaction with the customer.

V A CASE STUDY – THE CENTRAL PROCESSOR PROJECT

One of the first projects to use the anatomy approach was conducted between 1995 and 1999 at the Swedish telecommunication supplier Ericsson. The goal of the project was to develop a new *central processor* for the main Ericsson switching system; the AXE System. Ericsson is, and was then, the largest supplier of mobile systems in the world. The company was established in 1876 and is present in more than 140 countries today [18].

Traditionally, the products had been developed and released according to a schedule made up by Ericsson. However, at that time, the customers began to demand the time release of new products with planned and unplanned specifications, thus setting time frames in development projects. This very situation was new to Ericsson.

The new processor was to be state-of-the-art. It would include a 4-time increase in capacity, new functions, new mechanics, new firmware, a new real-time master and slave ASIC, lower electrical consumption, and a reduction in size and weight. At the time, there were no simulators that could manage the ASIC that was to be developed. As a matter of fact, several of the large ASIC-producers could not support the development project. It was considered the most advanced and complex ASIC ever developed!

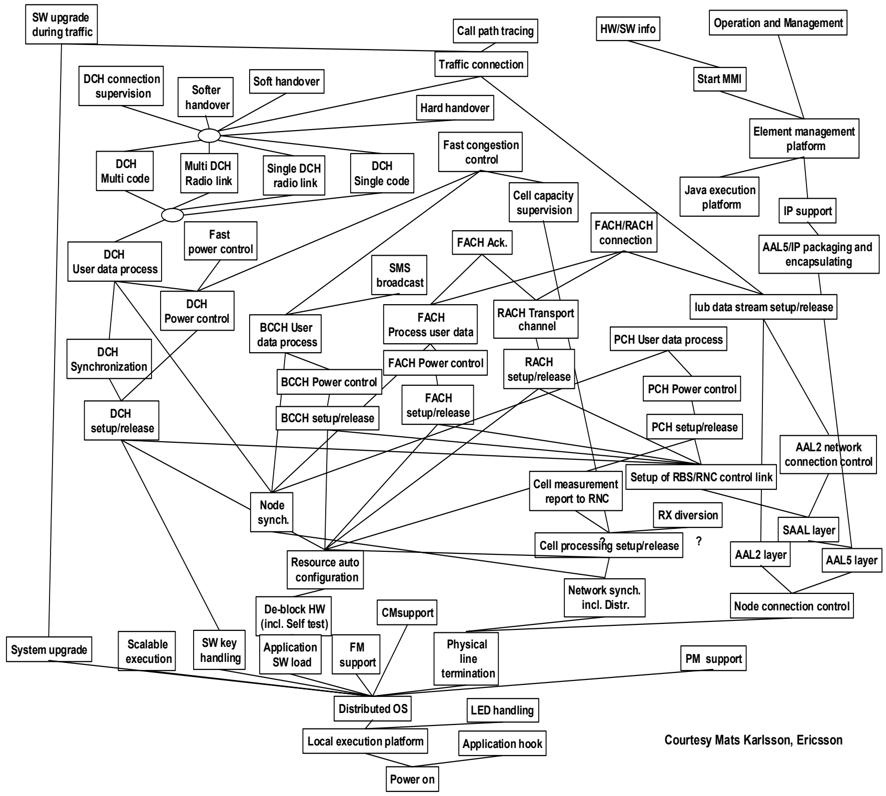

Fig. 6 The anatomy of the central processor

A Project organization

The overall project, which we will call *The Central Processor*, consisted of 7 major projects, of which several consisted of subprojects. The development projects were dispersed according to the location of the core competence. When the activity was at its peak, about 300 people were involved in the different projects located in one or more regions of Sweden, Germany, and Australia.

However, the project was not only challenged by cultural differences due to countries of origin, but also due to different corporate cultures. Many engineers in the project had been employed for 20 years or more in the same organizational setting. However, at the time, Ericsson began to reorganize the different parts of the company. Fixed telephone networks, mobile networks, and military networks each having different management styles and different approaches to system development were mixed. The reorganization implied that many people in management came from other parts of Ericsson with different ideas [2].

The Central Processor Project was divided into 4 organizational levels: *Total Project level, Project level, Subproject level*, and *Team level*. Within these there were 6 important functions or roles:

- *The Total project manager* was responsible for planning and controlling the overall project. He was also the one responsible for the delivery and acceptance of the product by the customer. The total project manager was replaced during the project.
- *The Project Manager* was responsible for a specific project, and reported to the total project manager. Some of the project managers were replaced during the project, and it was one of these managers who introduced the anatomy approach. This introduction was also supported by the new total project manager.
- *The Product Manager* was responsible for the product, i.e. that requirements regarding functionality, appearance, maintenance, standards, etc., were fulfilled.
- *The System Manager* was responsible for seeing that the quality of the functions in the specification was preserved in the system.
- *The System Emergency Board* was an instance used throughout the project. It was managed by the critical CPG project (CPG is an internal Ericsson name on one of the 7 projects). The reason it was managed by one of the projects was that they were responsible for basic testing and the system integration, and thus was the receiver for many of the internal deliveries. During the critical times of the project, the System Emergency Board met every day in between 12.00 and 12.30. It consisted of experts on both hardware and software, and, thus, could give advice and handle different problems as soon as they occurred. Anyone involved was welcome there to discuss their problems; however, people were sometimes called in to explain their status.
- *The Configuration Change Board* was more formal than the system emergency board and decided on change requests and changes. The configuration change board met at most once a week.

Kommentar: CPG: Central Processor Generator system

B Project planning

When the new project manager in the critical project (CPG) entered, it became clear that there was no control over the project status or when things should be done. As a result, the new project manager started to interview people involved in the project. It was concluded from the interviews that the project was considered too complex and risky to use a traditional approach. The experience was that network diagrams of complex ever-changing projects were unmanageable at the overall project management level. It requires too much effort to keep track of all the changes and implement them in the picture so the managers have an up-to-date picture of the project. Further, the “picture” is to complex to be used in the discussion with other actors, such as the customer, top managers, project members working in parts of the system, etc. At the same time, there was hearsay about an approach used in an earlier project at Ericsson: *The Japan Project*, when Ericsson became the first foreign supplier to get a foothold of the Japanese market for mobile systems [2]. The project managers’ experience from earlier projects was; “*when managing complex projects, there is a need for a general picture*”; and the approach used in the Japan Project provided such a general picture. Supported by the new management, that had experience from the Japan Project, the project manager of the CPG project decided to try the same integration-driven approach as in the prior project.

Anatomy definition

The anatomy was created from the customers’ point of view; in this case, the customer was considered being the one using the final system, not the internal customer ordering the project. The starting point in creating the anatomy begun by asking the question: “*What is the first thing the customers do? And then they do, and then, etc.*” What do they expect out of this product, what is the end result? The anatomy should describe the process in between, beginning with switching the power on, to getting out a stack of bills that can be sent to customers. The central processor can be started in two different ways; thus, two anatomies were created. However, only one was later used in the project.

The anatomy was created during several meetings. In the central processor project, creating the anatomy required around 7 meetings with selected key persons. The group included at the most 12 persons. At these meetings the project manager was not necessarily included, but line managers, system managers, system integrators and product managers were included. In this very project, informal group leaders were included as well. These people had a mix of hardware and software skills. Everyone involved was not active all the time, since their expertise was not needed all the time; some had knowledge of the start-up functions and some on other functions. However, the important issue was to create a shared understanding of the final system solution, and understand each others’ “language”. In this case, there were many discussions over where the anatomy ended. It was decided that the anatomy ends, where other systems begin as new applications.

When the anatomy was considered complete and agreed upon, it was frozen for the central processor project. Ericsson could still rewrite the anatomy if they wanted to, but the Central Processor project needed the frozen anatomy to create the integration plans.

Integration and project planning

The creation of the increment plan and the integration plan was not made within the same group of people that created the anatomy. In this process the project manager was in charge. The focus in this process was to be able to test and integrate the system as early as possible and also early customer deliveries.

The anatomy focused on functions. However, when these functions were transferred to the integration plan, the increments were called something related to what they should do. Sometimes, a larger system's name was put into the integration plan, even though only a small function of the system was going to be used. This, however, helped people to recognize themselves in the integration plan.

When the integration plan was created, it served as the basis for a tollgate decision to go on with the project. If things changed in the project, or the customer wanted to pay less, it was easy to cancel an increment or function, and still know how this effected the rest of the system.

In the studied project, the integration plan was created when the project was running, and before time was included in the integration plan there was a belief that one part of the project was delayed; however, when the plan was created they found out that they were on time. The function they provided was not needed until late in the project. Instead, the project manager found out that another part was late, and that the part did not have any resources allocated for the project at that time.

C Information management

The anatomy chart and the integration plan served as very useful information management tools. The pictures were drawn using PowerPoint and were updated every week. PowerPoint was used since everyone worldwide could handle the format. Further, the information was published on the Internet, as well as printed and mounted in the project room. Since the printed copies were laminated with plastic, the project management team could use whiteboard pens and draw directly on the anatomy or integration plan whenever formal or informal discussions were held.

Project revision meetings, called *Dalarö meetings,* were held every six months at different locations outside Ericsson's facilities. These meetings engaged around 30 of the key managers involved in the project; such as the total project manager, the project managers, group leaders, and some product and system managers. Each meeting had a theme; risk analysis, system integration etc. The main purposes, however, was to bring everyone involved together and discuss the status of the system and the project. One of the key contributors to the success of these meetings was the anatomy and the integration plan.

As in any system development effort, there were many changes and interface problems to discuss throughout the project. These issues were managed by the system emergency board, which could discuss and act upon them when and if necessary. For this purpose; managing changes, the anatomy and the integration plan were considered to be a very powerful tool.

The anatomy and the integration plan were also used as means of exerting pressure on the internal deliveries. The project manager of the CPG project said:

> "Without the integration plan that was created after the anatomy, we would never have obtained this much control over the project".

D The use of anatomies in other projects

The anatomy approach has been used for several years at Ericsson. At the unit for processor development that was described in the previous chapter has used the anatomy in approximately 75 projects. In the development of the 3rd generation of mobile systems the anatomy is used extensively. For example, between 1999 and 2002, approximately 140 main projects and subprojects used the anatomy to develop large software systems [15]. The impacts have been profound. Some of the nodes in this mobile network are among the most complex systems ever developed by Ericsson. In one node, the so called Mobile Switching Centre, several hundreds of increments were included in the anatomy. Some project managers claimed that the development of this node would not have been possible without the approach described in this paper (ibid.).

VI DISCUSSION

The Central Processor Project exposes a number of issues which are relevant for many development projects of today. Disorder, bordering on chaos, faced the project. This was due to a number of factors such as: new technology, the number of sub-projects distributed around the world, new customer relations, cultural differences, different experiences among the project participants, newly appointed managers, etc. Thus, there was an urgent need to find a way to acquire a shared overview of the project that all actors could accept. This could not be provided by the traditional project apparatus since this is geared towards resource, time planning, risk estimation, etc. As a result of previous positive experiences with this approach at Ericsson (dating several years back), the anatomy was suggested as a possible solution. In the following, we shall discuss how this concerns both traditional, technically oriented project planning issues as well as more socially oriented ones, such as meaning and understanding.

A Approaches to manage dependencies

The most important aspect when working with complex products is to work with how the parts are connected. To be able to do so, there is a need to identify and work with the dependencies and to have a picture of reality that every actor can agree upon [9]. One striking example of this is from the Central Processor project:

> "CPG Project Manager (PM): Before we did the integration plan we thought that RPH (a subproject) was delayed. But then we saw that we did not need their stuff until late, in fact they were perfectly on time. Interviewer (I): You had a different opinion about the dependencies in the project? PM: Exactly, it was the micro programming which was wrong, totally wrong. They didn't even have the resources in the project at that point in time. So they had to re-schedule everything they had to do. I: This is an obvious effect of the anatomy work? PM: Absolutely, it wasn't until then we saw how late we were. When doing the anatomy we realized that we would be late anyhow."

The traditional approach to project planning usually proceeds from the product structure. A *Work Breakdown Structure* (WBS) is defined, stating the order in which different activities are to be performed in order to develop the product parts. In defining the WBS structure, the dependencies between the activities are only implicitly controlled. However, it is the role of the network diagram to capture the dependencies between activities, not the WBS [12]. Nevertheless, in large projects, network plans become complex, and the consequences of actions most often unforeseeable. Further, network diagrams can appear overwhelming when it comes to maintaining them for dynamic projects, where frequent changes are the order of the day. Consequently, updating and changing the schedule may be very time-consuming [12]. This increases the risk of erroneous planning which may be reduced by using the anatomy as a complement to the WBS in the planning process, since the dependencies are explicit in the anatomy. In the studied project the anatomy approach was used as a tool for project management to achieve control of the project, and traditional project planning was used only to plan the increments individually. The shared view of what to do and in what order, given by the anatomy and the integration plan reduces the risk for misunderstandings and sub-optimizations.

In a study of another system developer organization, Eriksson et al. [4] reports on a model similar to the integration plan. In this case, a model called 'dependency diagram' was used to provide a picture of how everyone involved contributed to the final result. The idea behind the dependency diagram is similar to the models called Release Matrix [14] and Dependency Structure Matrix [4]. The difference, however, is that the anatomy concept provide a connection between the architecture of the system (the anatomy) and the integration plan that the other approaches are lacking.

B Making sense

The most important quality of the anatomy is that it enables the actors to see their context in relation to other contexts. This is achieved by a picture which is, preferably, drawn on one page. Based on this picture they can take proper actions to achieve a common goal. No sophisticated tools are necessary. Mostly, PowerPoint is used since it is easy to learn and commonly available. This observation indicates that the key element of the anatomy is its *signifying* properties [7]. It should be conceived of as a composite, shared sign which signifies action possibilities for various groups of actors. This conjecture is further supported by the following observations:

- Usually, names are not assigned to the dependencies. Just indicating the dependency appears to be enough.
- Easy-to-apprehend traffic light cues are used for controlling the progress of the project.
- No strict syntax and semantics are used in the notation of the anatomy. On the contrary, its layout gives a disordered and haphazard impression.
- Different types of entities are mixed in practice. Functions, activities, parts and states are used alternately depending on what seems to be most adequate.
- The integration plan is 'tilted' in order to signify a time line.

All these points indicate that meaning and understanding is in focus for the anatomy. The anatomy must be meaningful for the project participants. This line of argument is further elaborated in [16] where the anatomy is apprehended as a certain type of affordance [6]. The important insight from this argumentation is that there is no ‘correct’ anatomy in an absolute sense. The form and content of the anatomy, as well as the beginning and end of it, are to some extent arbitrary. For example, it might have been possible to include the engine block or other parts as well in the anatomy of the Otto engine in Fig 2.

The social character of the anatomy is reflected in the, sometimes very arduous, process of defining it:

> “Some kept on for two months drawing the anatomy. […] In one case with a mature product people could not agree (how the product worked) even if they have been sitting in the same corridor for 20 years”. (Project manager, CPG project)

These engineers had different views of how the system actually worked. In the process to create the anatomy the crucial dependencies had to be articulated and agreed upon. For that specific system, it was the first time they discussed which were the crucial functions in the system and the interconnections between them.

It is also important that the nature of the anatomy is understood. On many occasions, the actors mixed up the integration plan with the anatomy. Many engineers want to start directly with drawing the integration plan, and skipping the first two steps with the anatomy and increment plan. Also, in drawings, the anatomy parts and functions are often drawn in the same way as ‘boxes’. This often leads to confusion and lengthy discussions. In the past, it has been tested to draw the same diagrams using formal notations such as UML. These attempts however, often ended up in side discussions about the meaning of the UML-constructs. In order to avoid this and focus on the anatomy, a less formal but easier to understand notation is used. Nevertheless, the process to create an anatomy requires a strong process leader in order to keep the discussions focused.

Thus, the same system may be perceived differently depending on the purpose of the anatomy, the background of the actors, the availability of tools supporting the anatomy management, etc. At the end of the day, the validity of the anatomy is decided by its usability in the development practice. If the anatomy contributes to the achievement of the goals of the organizations, it will gradually acquire a status of ‘reality’ in that organization. Rather than discussing which the ‘correct’ anatomy is, the focus should be on achieving a good enough shared meaning of the anatomy which enables coordinated actions to be taken. If this mind-set is prevalent, it is likely that the signification process will become less awesome since the issue of ‘correctness’ is not at stake.

C Acceptance

The anatomy enforces a certain mind-set: “What is the first thing the customer does when he starts up the system? Push the start button!” This mind-set is operationalized as the principle that the system should be developed in the same way as it ‘comes-to-life’. This principle sometimes was hard to accept for some designers: “I’ll design this function in the end; I’ll start with the most difficult (and interesting) ones first.” Some actors experienced the anatomy as a threat against their professional knowledge: “It can’t be this bloody easy; I’m actually doing more difficult stuff”. Others claimed that they could not see their particular contribution and context in the anatomy. Thus, in order for the anatomy to be accepted by the actors it is important that it is defined in such a way that each actor can see both his context and its place in the overall picture.

> “What we missed in the CPG project was to split the anatomy in smaller parts so that the individual designer could understand where he participated and where he didn’t do so” (Project manager, CPG project).

In later projects each box in the overall anatomy have been having their own one page anatomy; and the result has been that each designer can see their contribution and also all the dependencies in their surrounding as well as in the project as whole. This is yet another indication of the social nature of the anatomy. The way the anatomy is laid out depends on the actors and their roles in the project.

D Project planning and control

Concerning the planning and control of the project, it is clear that there is a need for two types of plans – the integration plan based on the anatomy, and the ordinary project plan (time and resource plan) for each increment which provides the necessary logistics for the execution of the project.

Since the anatomy planning is integration-driven, it enables early feed-back to the customer. Some functions can be demonstrated early, something which contributes to building-up credibility between the customer and the supplier. Integration driven planning also makes it possible to test the production process early. Thus, the anatomy gives you the possibility to identify faults early in contrast to projects where the integration is done late in one step. Another important consequence is that the anatomy shows which design and verification activities can, at least in principle, be performed in parallel. In practice, this may not be possible to realize due to various reasons such as; lack of resources or access to critical equipment such system verification plants, etc.

Commitments and responsibilities are important aspects when coordinating a complex development project [4], [8]. The anatomy provides a *"push and pull"* concept where these aspects are clearly visible. There is a receiver for every delivery in the project, including the customer, and if some subproject is delayed this becomes very evident, something that wasn't always appreciated in the CPG project:

> "When you did progress control based on the anatomy it became very clear who is slacking, which is not very popular by many people. It becomes so evident on the map and that gives you hell. But that was really the truth." (Project manager, CPG project)

Thus, the anatomy makes commitments and responsibilities more transparent, which in turn makes it easier to control the progress of the project. Concerning the progress control, it is easy to show progress and problems with the help of the anatomy. A simple system of cues can be utilized for signifying progress, for example traffic light signals.

E Limitations and possibilities

There are some aspects that become more difficult when using the anatomy. A drawback of the integration driven way of working is that the configuration management of the project becomes more complicated:

> "But it becomes a bit messy and requires a very competent configuration manager. That person acquired a higher status since that person had to keep track of partial deliveries" (Project Manager, CPG project).

This in turn requires a tool supporting configuration management, and if the project is very complex, a tool to keep track of all the increments and dependencies.

Further, it can be difficult to motivate the cost (i.e. time and resources) that is required to create the anatomy and the integration plan. It is difficult to measure benefits such as a shared understanding and clarification of dependencies; however, the experience from several projects clearly shows the benefits of a concept such as the anatomy. Other difficulties in using the anatomy approach are that it can be hard to persuade the developers to think from the perspective of the customer. Further, it can be on a too high level, meaning that the people involved in the project don't see the complexity they are facing. Thus, there may be a need of anatomies on several levels. Finally, the approach is quite new, meaning that there are different views on how to use the approach as well as there is no defined notation to use. One striking example of this is that some projects at Ericsson draw the anatomy starting from the bottom and some is starting from the top.

By using the anatomy approach, the subprojects could be working more independently form each other. In a study by Adler [2], at the same company, he reported similar advantages when using this approach. Advantages are typically that products are built-up instead of broken down, and that projects are organized by building dependencies instead of minimizing them. Further, the system integration is performed early or continuously and interdependencies are seen as an engine for renewal. Progress control based on functionality tests and/or actor's subjective opinions help project management to work proactively and rapidly in real time. Finally, the approach was found superior in meeting both fixed and emerging targets.

F Future research questions

The Ericsson experiences show that the anatomy approach is a valid concept for planning and controlling complex system development projects. However, the approach has, to the best of our knowledge, so far been used at Ericsson only. Thus, transferability to other organizations besides Ericsson is an obvious issue. We claim that the anatomy, as a way of working, is applicable in many areas. However, this has to be validated by future research.

It is interesting to note that the increments in principle may be regarded as projects on their own. Thus, an anatomy based project may be apprehended as a multi-project. This raises the question of whether the anatomy can be utilized in managing a portfolio of projects, something which is currently receiving great interest. A topic for further research is then how to use the anatomy in connection with project portfolios.

Moreover, we need to address the issue of tool support for anatomy based planning and control. The anatomy itself can, as pointed out earlier, be drawn by simple tools like PowerPoint. On the other hand, the configuration management requires quite different tools. One example of this is the implementation of a Product Data Management (PDM) for supporting integration driven development at Ericsson [15].

Finally, the anatomy has so far been mainly used in relation to a given system. However, the anatomy perspective might be helpful in developing system architectures which enables easy-to-develop systems. After all, a system architecture, which is so complicated that only experts can understand it, will most likely give rise to problems during the development. Thus, the anatomy may work in two ways: as both an analytical and a constructive instrument.

VII CONCLUSION

The experience from Ericsson shows that using the anatomy as the basis for overall project planning and control has profound impacts on the success of projects developing complex telecommunication systems. However, the transferability to other settings needs to be further evaluated. Nevertheless, the anatomy provides a compact and comprehensible representation of the crucial dependencies between the system functions without getting lost in details. The definition of the anatomy is a signification process in which major stakeholders participate. The outcome of that process is a shared understanding about the system dependencies which in turn is a prerequisite for commitments, agreements and responsibilities in the project. Some of the benefits given by this approach are:

- Everyone's contribution is visible
- There is a receiver for every delivery - Push and Pull concept
- Find system faults early
- Visualization of real progress
- Able to work parallel in a controlled way
- If needed, early production and delivery is possible
- Overall System and Project view

In order to succeed with complex development you need to simplify to be able to control. The anatomy is one approach to doing so and we claim it can be an indispensable complement to traditional project planning methods in the turbulent environment of system development.

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