Product Driven Process Improvement PROFES Experiences at Dräger

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Abstract. The paper describes the experiences of Dräger Medical Technology in the ESPRIT project PROFES (PROduct Focussed improvement For Embedded Software processes). Dräger has participated as an application provider (industry partner) in the PROFES project and has implemented a software process improvement programme with the goal to improve product quality in the main areas of product reliability, fitness for use, and predictability of quality, time and cost. The paper describes the improvement programme from goal setting, via implementation of process changes, to evaluation of the results. The methods used in the improvement programme are goal oriented measurement (GQM) and software process assessment (BOOTSTRAP). Dräger has realised a tremendous improvement in process maturity through the course of the PROFES project (from Bootstrap level 1.50 to 2.75 in less than one and a half year). The paper will address the environmental factors that have facilitated this outstanding improvement in such a short time. The paper will focus on hands-on experience with the PROFES method in an industry partner and will, as such, have a significant contribution to the exploitation of the PROFES method in the industry.

1 Introduction

Traditionally there have been two different approaches in improving software quality: the product oriented approach and the process oriented approach. The product oriented approach tries to guide quality improvement by making product quality explicit, whereas the process oriented approach tries to improve product quality indirectly, by controlling and improving the software development process. The process improvement approach assumes a positive correlation between process improvement and product quality.

In an industry environment, the primary goal of a company is to sell products, not to improve processes. When quality improvement activities focus too much on the process without being clear about its effect on product quality, it is very well possible

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that effort is invested in activities that barely affect product quality. Also it is possible that the process improvement activities have effect on quality areas, where the product quality is already according to user/customer needs. It is therefore important to invest in process improvement activities that improve product quality where needed, and in those process improvement activities that are expected to have the most effect. The 'traditional' Software Process Improvement approaches lack this focus on product quality to a great extent. The PROFES improvement methodology is the first available method that realises this product driven process improvement approach.

1.1 PROFES Project

The method applied in Dräger Medical Technology originates from the ESPRIT project PROFES. The objective of the PROFES project [1] is to support the embedded systems industry with an improvement methodology that:

- focuses improvement actions on those parts and characteristics of the software development process that contribute most to the critical product quality factors;
- combines and enhances the strengths of product modelling [2], process modelling [3], process assessment [3], [4], goal-oriented measurement and experience factory[5], [6], [7], [8];
- is validated through case studies in three industrial organisations.

1.2 Dräger Medical Technology

One of the application providers in the PROFES project is Dräger, a 1.8 billion DM multinational company operating primarily in the fields of medical technology and safety technology, with limited operations in aerospace technology. It has about 8900 employees, of which over 5900 are employed in Germany. The three divisions of Dräger are Medical Technology, Safety Technology and Aerospace. The core business of Dräger Medical Technology is the development, production and service of gas monitors, single and multi-parameter patient monitors, fluid pumps, incubators and defibrillators for application in anaesthesia, intensive care, neonatal and emergency care.

The PROFES improvement programme has been carried out in the Workplace Management System (WMS) project at Dräger Medical Technology. The objective of this project was to develop a new generation of patient monitoring devices. The development activities took place at two sites: in Lübeck (Germany), and in Best (the Netherlands). The PROFES improvement methodology has been applied in Best.

2 The Analysis Phase

At the start of the PROFES project a quality investigation was started with the goal of identifying the product quality objectives and assessing the software development process.

2.1 Product Quality Objectives

Based on a history of many years in the medical equipment business and market explorations at the beginning of the project, the improvement objectives were drawn up for the WMS products. The objectives were subsequently prioritised in the following order.

1. Higher **reliability** of the overall product. This means a lower number of defects in the final product during operation by the end users.
2. Higher **fitness for use** of the overall product. This means that the product should give more functions required by the end users, and even more important, be able to support the process of the end user better.
3. Higher **predictability** of the quality, time and costs of the development of the product. This means that a qualitative product has to be completed in time, within the budget.

2.2 Software Process Assessment

A BOOTSTRAP [4] software process assessment was performed during May and June 1997 at Dräger Medical Technology in order to characterise the software development process and to identify strengths and weaknesses.

The overall assessment results are presented in the process maturity profile shown in figure 1. The profile presents both the overall R&D Department (Software Processing Unit, SPU) maturity and the WMS project maturity. The results show that the WMS project maturity is a little lower than that of the overall organisational maturity. The overall organisational maturity of the SPU is 1.75 and the maturity of the WMS project is 1.50. This indicates that the software development of the whole department was on its way from a Performed to a Managed process.

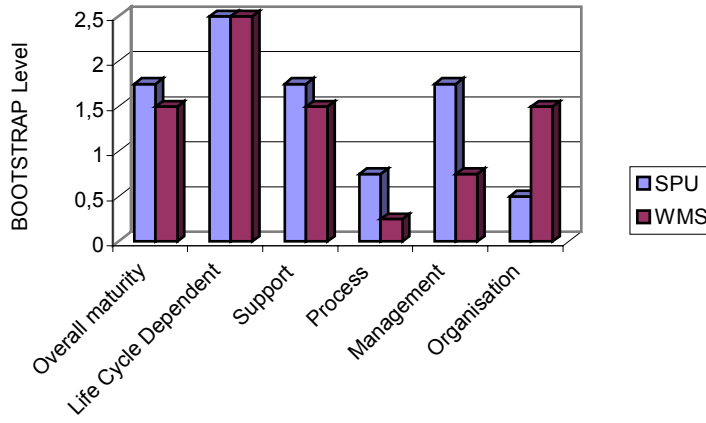

Fig. 1. The main characteristics maturity profile

3 Improvement Activities

Based on the recommendations of the software process assessment improvement activities were implemented in the WMS project. The improvement activities were specifically selected in order to achieve the product quality objectives. Besides these process improvement activities, a measurement programme was started to monitor the results of the improvements on process maturity and product quality. In sections 3.1 to 3.3 the improvement activities are presented for each of the product improvement objectives. In section 3.4 the measurement programme is discussed.

3.1 Reliability: Improvement Activities

The following improvement actions were taken with the objective of improving the reliability of the overall product.

- *Inspections*. In order to improve the reliability of the products, Fagan inspections were applied on requirements documents, analysis documents, design documents and test specifications.
- *Testing*. To verify the (high) quality requirements, an adequate test strategy was implemented and an independent test group has been installed.
- *Configuration management*. Configuration management covering all documentation has been defined and established at department level in order to manage changes to the product throughout the life cycle.
- *System and software architecture*. An architecture team has performed an extensive analysis and definition of the system and software architecture. The team consisted of members of both development sites with experience in embedded

systems development as well as object oriented development. Time and money was explicitly allocated for the architecture activities.

- *Incremental development*. To be able to get early feedback on the product quality, the products were developed in so called increments. Each of these increments take about six months and result in a working prototype, featuring a subset of the final functionality. These prototypes are tested in hospitals to get the required feedback.
- *Evolutionary development*. To be able to get early feedback on product quality, the team that developed the Bedside Monitor adopted a development cycle of six weeks. Each of these cycles results in a working prototype, featuring a subset of the final functionality. An independent test team tests these prototypes to get the required feedback. Furthermore the very short cycles make it possible to adjust the (new) object oriented based development process.

3.2 Fitness for Use: Improvement Activities

The following improvement actions were taken with the objective of improving the fitness for use of the overall product.

- *Improve customer needs management.* In order to ensure fitness for use of the product the customer needs policy has been redefined. Higher emphasis has been laid on ensuring interaction between the technical staff and the customers.
- *Co-operation between R&D and Product Marketing*. To ensure realistic product specifications, the specifications were made in close co-operation between the development and the product marketing departments.
- *Buy in system modules*. To be able to offer state of the art functionality, some system modules were bought in from world wide recognised market leaders on patient monitoring technologies.

3.3 Predictability of Quality, Time and Cost: Improvement Activities

The following improvement actions were taken with the objective of improving the predictability of quality, time and cost of the development of the product.

- *Continuous Integration*. The various parts of the product were integrated and tested as soon as they are available by a dedicated integrator. This includes software, hardware and mechanical components. This is to prevent unpredictable outcomes of the development and notice problems between these components in an early stage. In this stage it is easier to take these problems into account and easier to address them in the planning.
- *Subcontract management*. Because of the shift to system integration, the quality, time and cost of the WMS project largely depends on the various subcontractors. To organise this adequately, subcontract management was defined as one of the focus areas of higher management. Furthermore special groups are formed for the most critical suppliers, consisting of persons from product marketing, research & development, and the purchase department.

- *Problem Report Board*. The Problem Report Board (PRB) was started in order to support the process of solving defects. In the PRB, each defect is discussed and a decision is made whether and at what time the defect has to be solved. Also the defect is assigned to the right person. By installing the PRB a better prediction could be made of the effort needed to solve defects. This lead to a more accurate planning of the WMS project, because the right effort is assigned to solving defects.

3.4 Measurement Programme

In order to monitor the improvement activities a measurement programme was started. The Goal-Question-Metric (GQM) method [6], [7], [8] was used as the framework for the measurement programme. The GQM method identifies a systematic approach towards measurement and consists of the phases: planning, definition, data collection and analysis.

Measurement Program: Planning and Definition. The improvement activities, as described in the previous section, cover a wide range of activities in product development. It was impossible to measure the effect of all individual improvement actions and it has been decided to focus the measurement programme on the following major areas: reliability, inspection process and system testing.

The following measurement goals were defined:

- Analyse the *Product* with respect to *Reliability* for the purpose of *Characterisation* from the viewpoint of the *Project Management* and the *Engineers* in the context of the *WMS Project at Medical Technology in Best*.
- Analyse the *Inspection Process* with respect to *Effectiveness and Efficiency* for the purpose of *Characterisation* from the viewpoint of the *Project Management* and the *Engineers* in the context of the *WMS Project at Medical Technolog yin Best*.
- Analyse the *System Testing Process* with respect to *Effectiveness & Efficiency* for the purpose of *Characterisation* from the viewpoint of the *Test team* in the context of the *WMS Project* at *Medical Technolog yin Best.*

Measurement Program: Data Collection. In order to reduce the effort needed for data collection of the measurement data for the measurement programme the process was semi-automated. Several templates and tools were created to ease the data collection process in the daily work of the engineers. The data collection tools were created to assist the engineers by providing easy to use tracking reports and to facilitate the analysis of the measurement data. A quality engineer was assigned for the development and adequate use of the data collection tools.

Measurement Program: Analysis. The analysis and interpretation of the measurement data has been done in several feedback sessions. Feedback sessions are meetings of the complete WMS project team in which the measurement results are presented and discussed. In figure 2 and 3, a sample has been given of graphs used in the feedback sessions. The interpretation of the measurement data is not done by the quality assurance engineers, but by the software engineers and the project managers, as they are the experts with respect to the subject. The insights acquired during the feedback sessions were used to optimise the inspection and test processes.

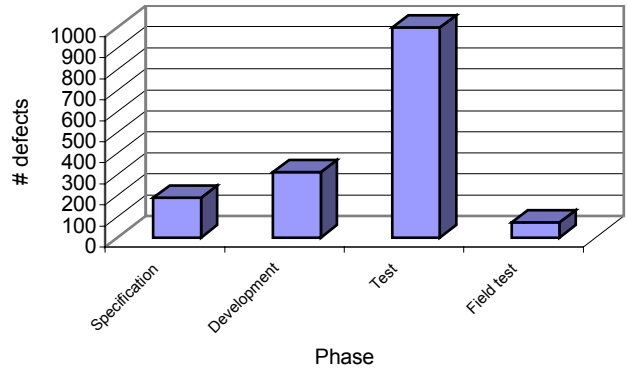

Fig. 2. Number of defects found per development phase

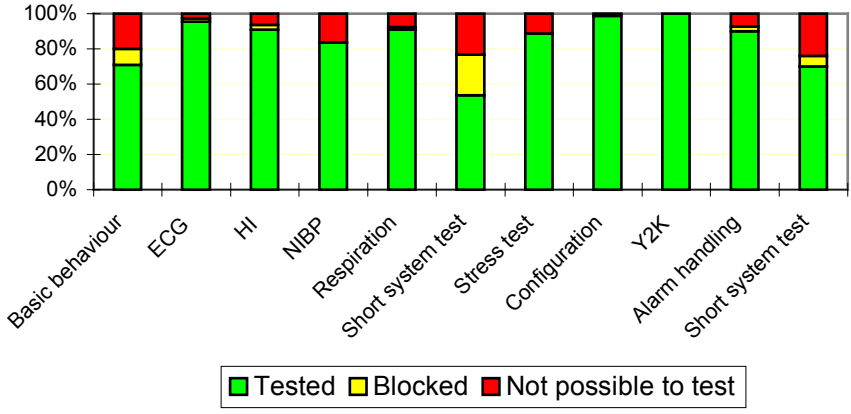

Fig. 3. Test blockage per test case

4 The Evaluation Phase

After the initial quality investigation improvement activities have been implemented, which addressed the strengths and weaknesses in the development process. Of course it is important to see whether these implemented process improvement activities have had the desired effect on the maturity of the process and, even more important, if the activities had the desired effect on software product quality. Therefore a second BOOTSTRAP assessment has been conducted and the product quality has been evaluated.

4.1 BOOTSTRAP Assessment

The BOOTSTRAP re-assessment was performed in July 1998. Whereas in the first assessment the complete software development process was assessed, in this assessment only those areas of the development process were assessed that were either:

- recommended for improvement in the first assessment, or
- identified by the organisation in the preparation phase.

The overall assessment results are presented in process capability profiles shown in figures 4 and 5. The results show a similar trend at department as well as project level. The capability level of all the processes assessed at both levels has risen significantly since the first assessment.

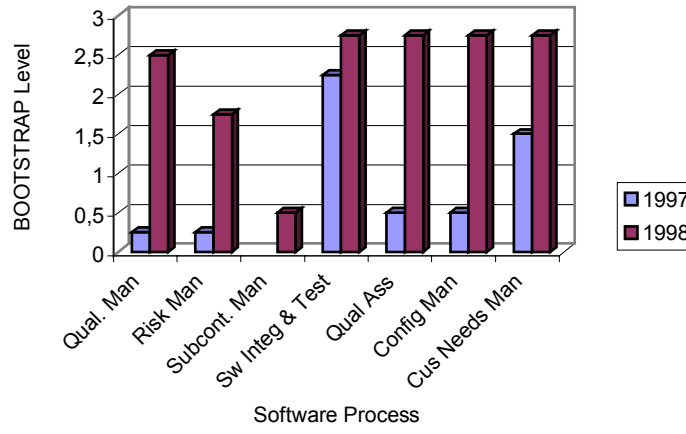

Fig. 4. Department level capability - Comparison

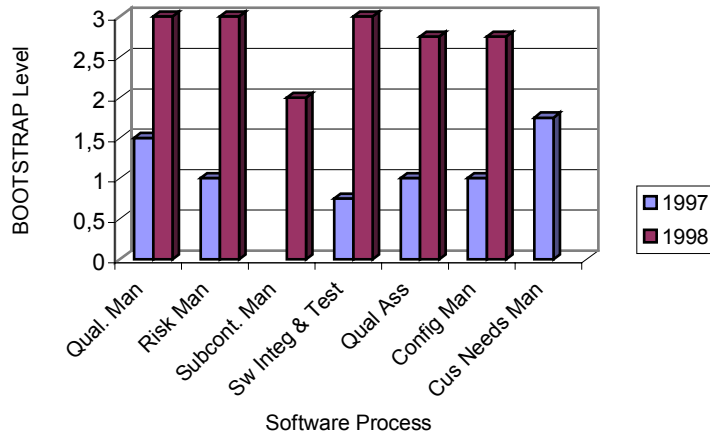

Fig. 5. Project level capability – Comparison

Figure 4 shows the department level comparison between 1997 and 1998. At department level, the maximum rise was in the quality management process (a rise from 0.25 to 2.50). This process was followed by a rise in the capability levels of quality assurance, configuration management, and risk management.

Figure 5 shows the project level comparison between 1997 and 1998. At project level, the maximum improvement is in the software integration and testing process (a rise form 0.75 to 3.00). Risk management, quality assurance and configuration management follow closely.

Considering that the gap between the first assessment and the re-assessment was only about 12 months, the increase in capability level of all processes at both levels is an extreme good achievement.

In May 1999 a final assessment was done for the two processes that had been changed during the last year of the improvement program: inspections (BOOTSTRAP SUP.4) and testing (BOOTSTRAP ENG.8). The main information source for the assessment was the GQM measurement data and interviews were held with quality engineers in Dräger. The improvement in these processes were driven by the measurement program and resulted in a rating for the inspection process of 3.75 and the testing process of 3.50.

4.2 Product/Process Dependency Modelling

In order to check the impact of the process improvement actions on product quality the Product/Process Dependency modelling approach is used [9]. Product/Process Dependency models (PPD models) are one of the key elements in PROFES. A PPD model presents the relationship between the software process and the quality attributes of the product that is developed by this process.

The following achievements have been realised related to the product quality goals:

- With respect to product reliability it is good to note that only 4,75% of the defects was found during handling tests in the hospital. As hospital environment can never be fully simulated within the development department and because the handling tests were executed early in the project, this number is considered to be a good result.
- The functionality of the working product that was available at the end of the last increment, proved to be close to final during the second round of handling tests in the hospital. This gives quite a good indication of the fitness for use of the final product.
- Also the fact that the increments were finished on the planned dates, resulting in working products that were received well in the hospital and by the Product Marketing department, indicates that the predictability of the WMS development project was good.

The validation of the relation between a process change and product quality remains a difficult task. It is often hard to assign product quality improvements to specific process changes, because many changes have been implemented during the improvement programme. In the course of the PROFES project, the Product/Process Dependencies models have been derived for the major process improvement activities.

Table 1. Product/Process Dependency models

Product Quality	Process Change	PPD Validity
Reliability	Problem Report Board	Defects assigned to the right person to be solved
Reliability	Inspection process	Find defects in documents, especially in early phases in the project 8615 defects found during inspections
Reliability	Subcontractor management	Stronger parameter algorithms
Reliability	People competencies	Improved productivity of staff
Reliability	Evolutionary development	Very frequent testing increases reliability
Fitness for use	Inspection process	Assure the right functionality is implemented 4478 defects found in specification documents

Fitness for use	Subcontractor management	Stronger parameter algorithms
Predictability of quality, time and cost	Problem Report Board	Improved planning of defect solving
Predictability of quality, time and cost	Continuous integration	Early integration shows problems in an early stage
Predictability of quality, time and cost	Evolutionary development	Frequent milestones shows project progress

5 LESSONS LEARNED

In this section, the lessons learned during the PROFES project are presented. The purpose of the lessons learned is to provide guidelines for those organisations that will adopt the PROFES methodology to improve their product quality objectives.

- If data collection has been integrated in the daily work, i.e. if data collection also helps a person to do their work or at least does not bother their work too much, that person is more inclined to invest the effort to collect the data.
- It is difficult to hold feedback sessions in a large group at regular intervals. A number of reasons that may occur are: measurement data too late, waiting for extra measurement data to become available, holidays and time pressure on the project.
- For the measurement programme about system testing, setting hypotheses was skipped. Later on during analysis this was troublesome.
- Product/Process Dependency Model validation is a difficult task. A large number of factors seem to influence each other in realisation of improvements.
- Focusing on product improvement makes the improvement programme more purposeful, which helps for the motivation of the involved engineers.
- Simple metrics already provide good results. With low cost it is possible to draw useful conclusions.
- Support for the improvement programme by management really helps in implementing process improvements. Also involving the engineers in the improvement programme, using their input during measurement programme definition, and letting them make suggestions for improvement provides great benefits.
- Involvement of the engineers during the definition phase of the improvement programme and management support for the improvement actions helps in motivating the staff for the improvement programme.
- Setting up good data collection tooling takes considerable time, but can help greatly during data collection, because it makes it easier to collect the data. Because this increases the probability for success of the measurement programme it is well worth the effort.

6 Conclusions

This paper presented the practical application of the PROFES methodology at Dräger, illustrated with experiences from a real-life development project. The main conclusion is that the PROFES methodology puts the product in a central position in an improvement programme. Therefore the specific needs of the company are better addressed. As a result, high commitment of the project team and of management towards the improvement programme is established.

Many process improvement activities have been implemented during the improvement programme. This resulted in a significant rise in process maturity (BOOTSTRAP level 1.50 to level 2.75 on the project level). The specific processes inspections and testing, for which a measurement program with regular feedback was established, were even rated respectively level 3.75 and 3.50 at the end of the project.

Because many process improvement activities have been implemented simultaneously, it is difficult to validate the relation between a particular process change and product quality. Nevertheless, it proved to be possible to deduct this relation using the Product/Process Dependency model.

During the course of the PROFES project, Dräger has shown a significant improvement in product quality as well as process quality. A systematic approach to improvement, as defined in the PROFES methodology, has supported the realisation of these improvements to a great extent.

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