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Applicability of Acceptance Test Driven Development in Integration and Verification Process in a Large Scale Company
A Case Study

Bachelor of Science Thesis in Software Engineering and Management

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Applicability of Acceptance Test Driven Development in Integration and Verification Process in a Large Scale Company: a case study

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Abstract

This paper presents a case study that is conducted in Network Integration and Verification (NIV) at Ericsson AB, a large-scale telecommunication software and systems company. Ericsson is transitioning to delivery which is the reason why they are interested in improving their integration and verification process. By modeling and investigating the current process, and based on the collected data, we were able to identify certain issues related to inter-department communication in the current process. A process improvement proposal inspired by Acceptance Test Driven Development (ATDD) was created. In the end, we experimented and evaluated our proposal through a workshop which gave us positive feedback regarding the proposed process. The result of the study indicates that ATDD can be beneficial to improve the communication and thus the efficiency of the product test process at a large scale company.

Index Terms—**process modeling, process improvement, ATDD, case study**

I. Introduction

A. Problem Statement

The department of Network Integration and Verification (NIV) in Ericsson is searching for a possible alternative development process that will improve the efficiency of their integration and verification process. They are interested in applicability of Acceptance Test Driven Development (ATDD) in their department.

NIV department is in charge of high-level testing, integration and verification of the Packet Core solutions, which includes various products and features. Different parts of the solution are developed and tested by different parts of the Product Development Unit (PDU). The products are then handed over to NIV to perform end-to-end tests. If any issue is discovered, it will be reported to the development team. Otherwise, the product will continue in the process, it will be handed over to Product Introduction (PI) department and be prepared to be presented to the customer and the market.

Ericsson is transitioning to continuous delivery, which means the product-to-market time will be shortened from 6-12 months to 1-2 months. They are transitioning from independent software releases to monthly software service subscriptions.

By conducting preliminary research, we are able to detect certain issues that occur in the current process. For example the test engineers from NIV sometimes prioritize test cases differently compared to the expectations of the product development.

B. Purpose of the Study

The purpose of this study is to identify issues in the integration and verification process in a large scale company, and investigate the possibility of applying ATDD to improve the process.

C. Research Question

Our main research question is specified below:

How to model the end-to-end test process of a large scale company and identify the issues in the process in order to improve it?

A research sub-question, that has been identified by Ericsson, is also given below:

How can Acceptance Test Driven Development improve the efficiency of the integration and verification process in a large scale company?

D. Related Work

ATDD has not been studied thoroughly since the time of inception. Some existing studies mention the topic, but not many case studies or empirical studies cover the topic. One study by Haugset and Stålhane [1] evaluated how ATDD can be used as a requirement engineer practice. Their findings suggest that the use of ATDD can mitigate some of the risks involved in requirement engineering. This result is further investigated from a different perspective in our study.

Another study by Hoffmann et al. [2] investigated test-driven development including ATDD, together with problem based learning for a real time system, and presented a proposal how it can be applied. The study covered the whole aspect of test-driven development, our study compared to this focuses only on ATDD.

In another study, Petersen and Wohlin [3] proposed measures to evaluate how to improve the software development process to increase Lean and Agile concepts like flow and throughput in order to increase the responsiveness to customer needs. These concepts are also present in our study but we focus on the process, however, in this study we measure the qualitative opinions of the participants in the process.

The field of business process modeling has been studied extensively over the years. Several different techniques and frameworks can be used to model the process with different advantages [4]. In an effort to simplify the practice of process modeling, Mendling et al. [5] designed the Seven Process Modeling Guidelines (7PMG). These guidelines will be implemented to the extent that they are applicable in this study.

II. Background

A. Acronyms

In this report we are using a few acronyms which are described below:

- APO - Area Product Owner
- ATDD - Acceptance Test Driven Development
- BPMN - Business Process Modeling Notation
- LSV - Last Software Version
- NDO - Node Design Organization
- NIV - Network and Integration Verification
- OPO - Operational Product Owner
- PDU - Product Development Unit
- PI - Product Introduction
- TA - Test Analysis
- TDD - Test Driven Development
- TE - Test Execution
- TS - Test Specification
- XCT - Cross Competence Team

B. Case Company Description

Ericsson is a global company developing products and services in network and mobile communications.

The NIV department handles the verification of the Packet Core solutions from an end-to-end perspective. This is done by request from different stakeholders within Ericsson depending on their needs. These stakeholders are usually different Node Design Organizations (NDO) who develop the different components (i.e. nodes) that the Packet Core solution consists of. When, for example, a new feature has been developed in any of the nodes, the NIV department will develop and run the necessary tests to verify that the feature is performing as expected in the complete network. This acceptance test is the last test phase before the feature can be sent to the Product Introduction department for customer introduction to do their acceptance test.

C. Test Driven Development

Test Driven Development (TDD) is a style of software development where tests are written prior to code development in small iterations: test cases are written to describe a feature, then code is written in order to just pass that certain test case, and when test has passed the code is refactored [6][7][8]. TDD is suggested to provide various benefits to the development process such as improved quality and higher test coverage [7].

D. Acceptance Test Driven Development

As TDD, ATDD also creates tests before implementation. ATDD encompasses acceptance testing, but highlights writing acceptance tests before developers begin coding. The major difference between TDD and ATDD is that acceptance tests are from the user's, or customers, point of view [9][10], which is what the NIV department tries to

achieve with end-to-end tests. ATDD helps with communication between the customers, developers and the testers. Better understanding of customers' needs can significantly reduce rework rate [9]. This method is an Lean and Agile process of development encompassing many of the principles. It facilitates collaboration between the different stakeholders, and produces working software that satisfies the acceptance tests, which are Agile principles. It also will reduce waste by limiting the flow back from test to development by creating the tests upfront which is one of the Lean principles [9].

E. BPMN

Business Process Modeling and Notation (BPMN) is a method for graphical representation of a model [11]. It is used as a notation standard for describing and modeling a business process with common elements, it has emerged to become an industry standard [11][12]. BPMN has evolved to its current version, 2.0, by incorporating many of the aspects of other modeling languages such as UML Activity Diagrams, UML EDOC Business Processes, IDEF, ebXML BPSS, ADF, RosettaNet, LOVeM, and EPC. There has been some criticism towards BPMN, such as ambiguity and overlapping elements [13][14][15]. A case study by Muehlen and Ho [16] found that by using core set of elements, BPMN helped to communicate and facilitate the change of a business process with the participation of the employees. They state that the use of BPMN in industry mainly consisting of the core set of elements, leaving out the extended set, was sufficient for the needs of the companies.

III. Research Methodology

In this thesis work, our goals are to:

1) Investigate and model the current process in NIV.
2) Understand what changes would the NIV members like to see in their current process.
3) Understand how TDD/ATDD can be applied in industries.
4) Investigate if ATDD is applicable to Ericsson.
5) Propose a process improvement plan that is suitable and applicable to NIV. The plan applies ATDD.
6) Experiment and validate the improvement plan with a workshop.
7) Find out whether or not NIV team members would choose to apply the proposed improvement to their process in the future and why.

A. Data Collection

Data collection plan is demonstrated in Table I, which reflects the goals stated above. Both first and second degree data sources were collected:

- First degree: interviews, survey, meetings and workshop.
- Second degree, observation, artifacts studies and literature review.

At the early stage of the study, in order to gain a general view of the current process as well as NIV members' opinion on the current process. We conducted early stage interviews with NIV members of different positions. To achieve a more comprehensive view, in parallel to the interviews, we sent out an online survey, consisting of similar questions to the interviews, to the entire department. Since both the interviews and survey results were relatively subjective understandings and opinions, we studied internal artifacts of Ericsson to assist process modeling.

Apart from planned interviews, we have also arranged meetings with other employees from different departments who have valuable input to our investigation. They include Line Manager and Area Product Owner of Network Integration and Verification department, Quality Manager and Process Methods & Tools Manager of Process Method & Tools department, System Manager of Node Design Organization etc.

While investigating and modeling their current process we were able to identify certain issues in the current process. A process improvement plan was proposed based on the data we collected during interviews, meetings, literature review and internal artifacts studies.

In order to evaluate the proposed improvement plan, we organized a workshop with some NIV members and a System Manager. They were instructed to perform tasks implementing the proposed process. Audio records as well as observation notes were taken.

After the workshop we conducted post-workshop interviews with all participants, they gave feedback to the workshop as well as their opinions on the proposed process.

Goal	Data Collection	Subject
1, 2, 4	Interview	members within NIV and PI department
1	Artifacts Studies	Ericsson artifacts
1, 2, 4	Survey	entire NIV department
3	Literature review	selected literature that is related to applying ATDD in industry
3, 4	Meeting	Change Leader[1] from Process Method&Tools department[2]
1, 4	Meeting	Program Manager and APO in NIV
5	Previous interviews and meetings, literature review, artifact studies	Ericsson employees; related literature
6	Observation and notes from the workshop	a team with selected Ericsson employees from NIV and PDU
7	Interview	workshop participants

TABLE I. Data Collection Plan

Each data collection method is further discussed below:

1) Artifact Studies: We have gathered different documents from Ericsson that describe their process and organization. These documents were selected from their internal digital documents archive for the department of NIV. From theses documents we have extracted the different activities, flows and roles that are parts of the end-to-end verification process. This data have been used together with the data from the interviews and the survey to model the process using BPMN notation.

2) Early stage interview: Early stage interviews aimed to gain more insights to the current process from different perspectives by interviewing employees of different positions in NIV and PI. We also solicited their general ideas and impressions on ATDD and TDD. Subjects were mainly

[1]Change Leader is a role in Ericsson who has expertise in process and process improvement.

[2]Process Method & Tools department provide tools that is used for verification process.

members within the NIV department. Since we want to study the process in NIV, members of the NIV department are the best subjects since they are the people who applies the process on a daily basis. The interview questions can be found in Appendix A.

We conducted a trial interview with a NIV tester in order to discover if there was any question that was misleading or creates bias. After the trial interview we made some minor changes to the interview questions, for example we changed the sequence of some questions. We have also added probing questions to instruct the interviewee to elaborate their answers when needed. Since the trial interview questions do not have significant difference from the improved interview questions, we included the results of it in our collected data.

The initial interviewee list was created by the NIV line manager. The line manager selected team members who he believes are good interview subjects. Selection criterion was that the interviewees are relatively experienced in the team so that their experiences and knowledge can provide important insights regarding the current process [17]. The risk we faced is that the selection is subjective based on the line manager's point of view, however this was not a major risk because as a line manager he has daily contact with all his team members, therefore he knows who has stayed in the team for a relatively long time. During the interviews, the interviewees referred some of their colleagues to us and suggested us to interview them as well. In the end, six individual interviews were conducted, the interviewees consist of one line manager at NIV, three testers at NIV, one manager at PI and one Technical Test Coordinator.

3) Online Survey: In parallel to the early stage interviews, we created an online survey that has similar questions as the interviews. The questions are presented in Appendix C. The aim of the survey was the same as the early stage interviews, to gain insights of the current process from different perspectives and to get their general ideas and impressions on ATDD and TDD. The goal of this data collection method was to collect more data points. The link of the online survey was sent to all members of the NIV department via internal email.

4) Workshop: The goal of the workshop was to verify our improvement proposal which can be found in Section IV-C. The participants consisted of a testers team and a System Manager from the Node Design Organization. The tester team included two NIV testing engineers, they had both been interviewed at the early stage interviews. The System Manager had also met us to discuss the current process at the early stage of the study. Therefore they all had a general idea of this study.

The workshop was 2 hours long, it consisted of four activities: requirement meeting; test analysis; test specification and review meeting. The requirement meeting took 30 minutes. The rest three activities were self organized by the tester team, the goal was to finish all three tasks within 1.5 hours.

One of the System Manager's responsibilities is to manage system requirements, therefore we asked him to help to come up with a requirement for the workshop that was based on a real world requirement. The requirement needed to be concise and in a small scale so that the tester team were able to analyze it within a two hour time frame.

The skills required of the participants prior to the workshop are:

- NIV testers are familiar with the current process.
- NIV testers are capable of and have experience to test analysis and test specification.
- System Manager has a good understanding of the task prior to the workshop.

Data collected during the workshop were audio records and observation notes taken by the researchers.

5) Post workshop interview: Stage 2 interview aimed at getting feedback on the proposed process as well as the workshop in general. We conducted individual interviews with all three participants within the first week after the workshop. The interview questions are available in Appendix B.

The goal of the interview questions was to learn and understand:

- Their general opinion of the workshop.
- Does the requirement meeting prior to Test Analysis affects their understanding of the requirements positively or negatively.
- What do they think are the differences between the current process and the proposed process.
- What are the advantages and disadvantages of the proposed process.
- Whether they think the proposed process is feasible in real life.
- Personally whether they would like to implement the changes.

B. Data Extraction and Analysis

All data we collected were qualitative data [18]. Data sources included internal artifacts, survey results, interview audio records, workshop audio records and observation notes taken by the researchers.

Audio records during interviews and meetings were transcribed manually by the researchers. Other than conversation transcription, the interviewers also wrote down when the interview was, where did it take place and basic information about the participant such as the name and the position.

1) Data coding: To extract data from the early stage interviews transcriptions, online survey results and post-workshop interviews, we used a data coding method. First of all, categories are created, they are summarized from interview/survey questions. Secondly all relevant words, phrases and sentences are coded and organized to the relevant categories. Lastly similar codes under the same categories are merged and summarized. The example of data coding can be found in Appendix D.

IV. Results

A. Current Process

This section describes the current process in the NIV department at Ericsson including the roles of the participants. From the data that was collected through the interviews, survey and the different artifacts such as process documents and test records, we have modeled the process that is currently performed at the NIV department using BPMN notation Fig. 1.

1) Roles: These are the roles that have active parts in the current process.

- Test Engineer - Tester in the cross competence team (XCT).
- Scrum Master - Supporting and coaching role for the team who focuses on team effectiveness. Remover of obstacles.
- Operational Product Owner (OPO) - In charge of communication between the XCTs and stakeholders. For example participate in backlog prioritization and defining the tasks for the team. Responsible for task pre-study.
- Area Product Owner (APO) - Overall responsible for backlog prioritization and handling features that have not been assigned to any XCT.

2) Description of Process: The process has two phases: the initial phase and the main testing phase. The initial phase consists of determining whether the NIV department should be involved, collecting inputs and scheduling the tasks. The activities in this phase consist of pre-screening, pre-study, project prioritization and scheduling the task for the team of testers. The input to start the NIV process is a request from one of the stakeholders, for example different Node Design Organizations (NDO), which is shown as the start message in Fig. 1. These requests are either classified as internal or external. Internal requests are the regular re-occurring tasks done by NIV. External tasks are more independent requests from the organization. The *pre-screening* activity is done if the task is external. If the
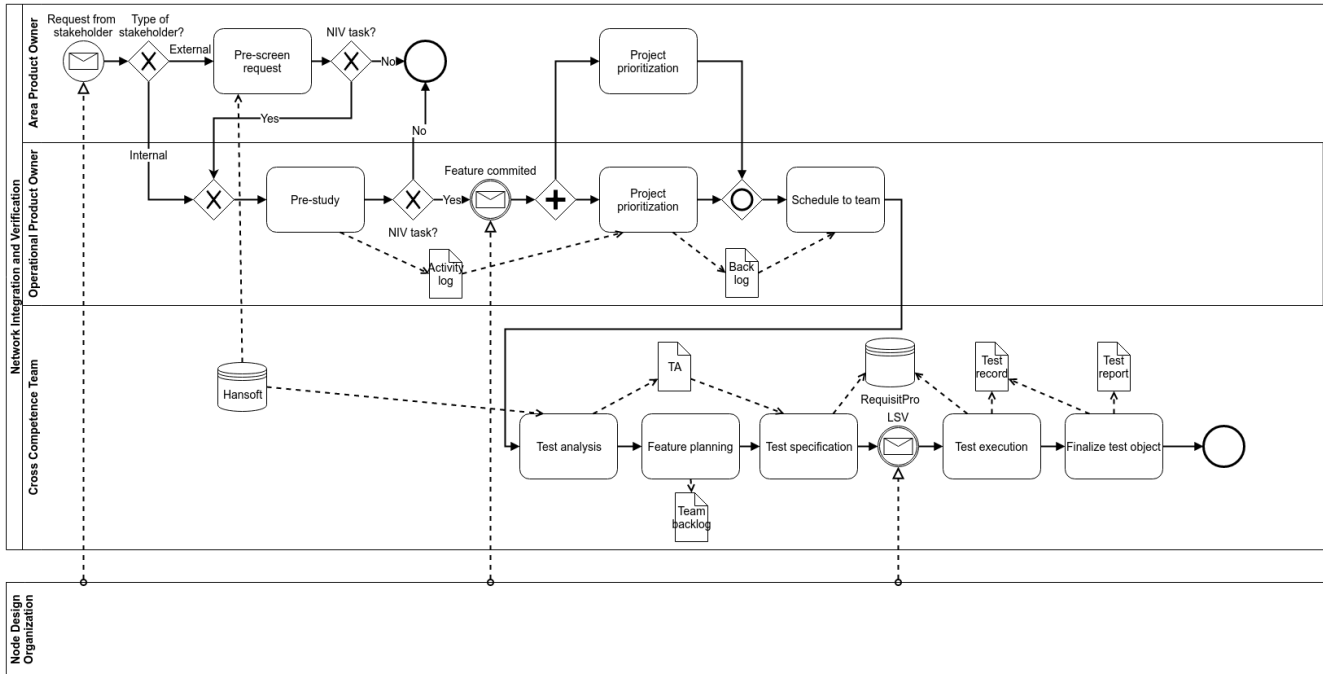
Fig. 1. Current Process

request is not relevant to NIV the process ends, represented with an end event in Fig. 1. The next step is the *pre-study* in which the OPO estimates the test scope, time, cost, etc. In this step the task is again evaluated if NIV is needed or not, if not, the process ends. The output of pre-study is added to the activity log. Once NIV team receives feature commit from NDO, POs (both APO and OPO) starts with *project prioritization*. The output of project prioritization is updated on the department backlog. The next activity is to *schedule the tasks* in the department backlog to the different XCTs.

The main testing phase involves the work of the XCT that will perform the main testing activities. The steps in this phase are shown in the lane for the XCT in Fig 1. The first activity in this phase is *test analysis* (TA). The input of the TA is the use case that is gathered from the tool HanSoft. The TA identifies the scope of the test, test environment, required tools, limitations and risks. The following activity is the *feature planning*. In this activity the task from the department backlog is broken down into smaller tasks, they are then estimated and added into a team backlog. Dependencies are also defined during feature planning. The next activity is the *test specification*

(TS) that specifies the test cases that will be run. The input for TS is the TA and the output is registered in the tool RequisitePro. Once the NIV team receives Last Software Version (LSV) from NDO, they continue to the next activity which is the *test execution* (TE). This activity consists of setting up and configuring the system under test and then executing the tests. The results from TE are registered to the test cases in the TS in RequisitePro, and a test record is generated in the NIV web portal. The final activity is to *finalize the test object*. In this step a test report is written and the test records are updated. During the test phases when the XCT runs into any issue, it is solved by either direct communication with the NDO, or via APO's weekly meeting with the NDO.

B. Advantages, identified issues and proposed changes

From the data we collected during the early stage interviews and surveys regarding their current process we identified some advantages as well as several factors that influence their process negatively. These findings are important factors to consider while proposing a new

process, we would like to improve the identified issues while keeping the advantages.

1) Advantages: Tester A expressed during the interview that having a common backlog is an advantage, which is good for prioritization as well as communication between NIV and other departments. Line Manager B said that the Lean and Agile Way of Working is an advantage, "In an agile process you talk about continuous improvement, which I believe is both a way of improve Ways of Working and being able to deliver faster, better throughput" Technical Test Coordinator C addressed the importance of Operational Product Owner (OPO), who is responsible to get involved in early study of documentations and therefore has full control of the work.

Seven of the twelve survey answers stated that the advantage of the current process is that it is simple, structured and easy to follow. "It is straight forward with some flexibility.", one of them said. Two participants mentioned that the current process encourages team empowerment which is another advantage. Other advantages are mentioned as well, such as a well-defined test scope; possible to find information and documentation review process with NDO. One participant answered "none" to the advantage of the current process.

2) Identified issues: Tester D identified the bottleneck in the current process is setting up test environment which is time consuming. The same applies to building up knowledge. Tester A said that "the common backlog requires same knowledge in all teams", therefore all teams should be prepared with the same competence and environment to take all different types of tasks on the backlog. He also mentioned that the teams are aware of the issue and are working on mitigating single competence by different knowledge sharing programs and activities.

Some teams in the NIV department have been transitioning from feature testing of physical nodes to both feature testing and system testing of virtual nodes in cloud environment. The transition is still undergoing and the new process and Way of Working is not yet set. Tester A said that they are working on merging the Ways of Working and team setup of the physical and cloud environment. The bottleneck of merging is the lack of competence since working with cloud environment requires new technologies. Another obstacle is that "the cloud environment is not as mature therefore problem occurs for example to build new labs.", said Tester A.

As mentioned in the previous section, OPO is in charge of communication between the teams and other stakeholders such as NDO. Tester E addressed a drawback regarding this, since "your understanding depends on someone else, then you could miss something, the test specification maybe is not fully covered."
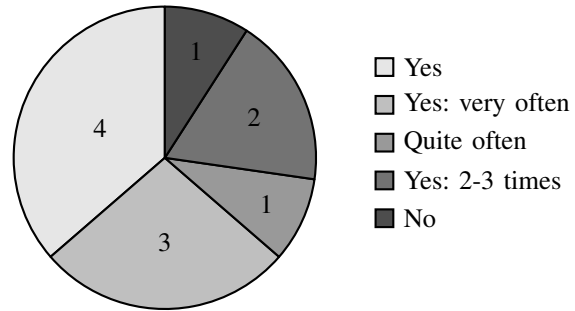

Fig. 2. How often is input misaligned?

Line Manager B said that one of the bottlenecks is that "not all processes and all departments are really lean", some teams do not focus on flow efficiency, instead they "lean much harder on resource efficiency."

From the survey, the most mentioned disadvantages are: too much paperwork during TA and TS; time consuming in environment setup; disconnection to customers: "we would be able to test more efficiently if we knew what problem the customer actually try to solve/knew customer priority". Some answers showed that there is redundant documentation review, and on the contrary, some said that early review of TA is lacking.

When asked "In the past few months, did you encounter any case where you did not receive the right input on the right time? If yes, how often?", 10 out of 11 testers answered yes. Out of the ten positive answers, 40% suggest that it happens very often or quite often as showed in figure 2. 'Very often' means misaligned input is received 20-30% of the time.

3) Proposed changes: Tester D suggested that NIV can start tests earlier in the process, which is supported by two of the survey answers as well. Tester E thought that direct discussion with design department before test case development will be beneficial in order to "design the test case in a better way". Technical Test Coordinator C suggested direct interaction between the team and the System Managers. Similarly, survey answers suggested more involvement of NIV in the process; clearer requirements and less changing in planning.

Other proposals were made as well, some hoped to have less documentation before testing and use one tool for all information; Tester A suggested to change team's Way of Working from Sprint to Kanban and Line Manager B thought that they should emphasize flow efficiency.

C. Process Improvement Proposal

Ericsson is transitioning towards continuous delivery and integration, which requires a shorter development cycle. This process improvement proposal aims at a shorter
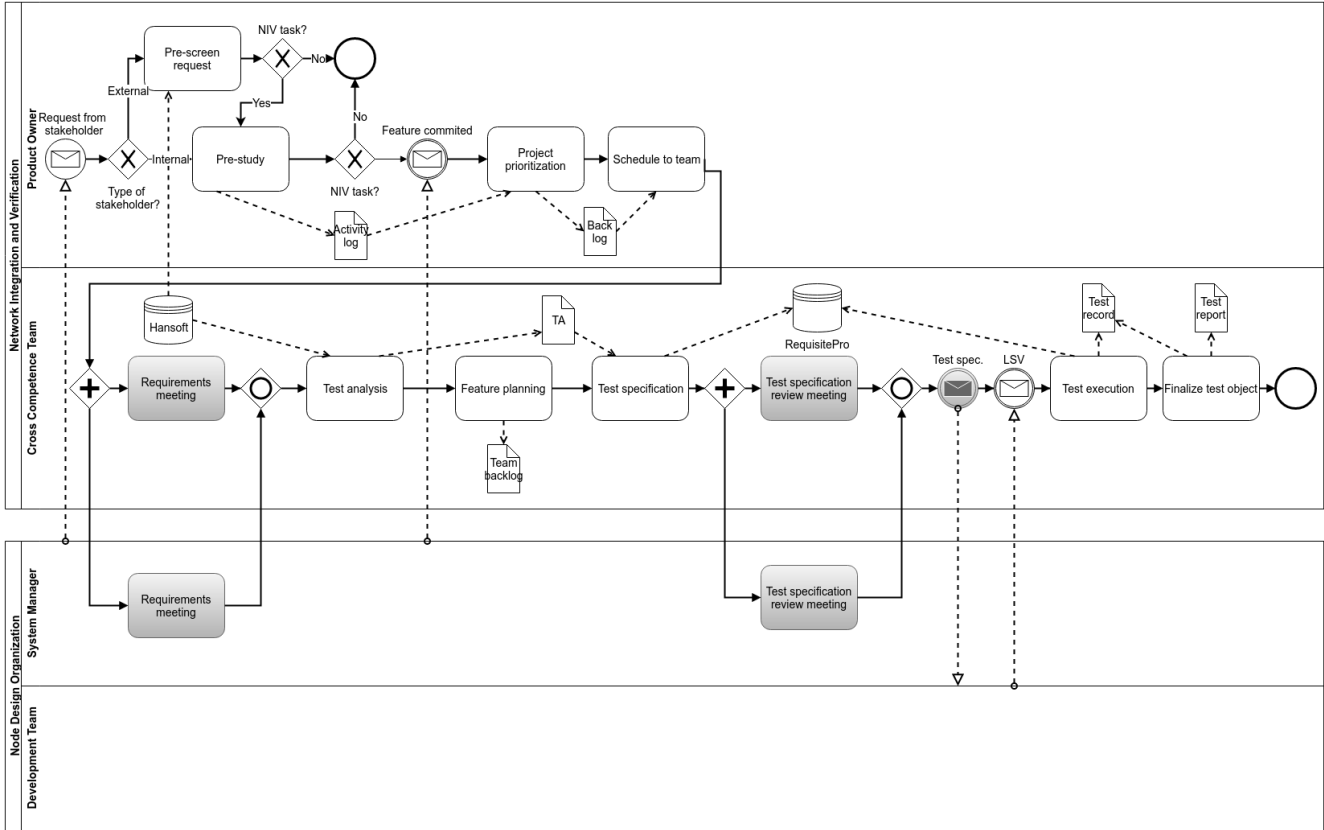
Fig. 3. Proposed Process

feedback loop between NIV and other stakeholders, and receiving more accurate information from NIV's perspective. These changes should not only improve the effectiveness in the Integration and Verification process, but also benefit Ericsson as a whole by improving the mutual understanding between design, development and test departments. The proposal is inspired by the concept of ATDD.

We propose to arrange a requirement meeting before Test Analysis as well as a review meeting after Test Specification between the NIV tester team and the System Manager of NDO. These activities are seen highlighted in Fig. 3. During the requirement meeting, the System Manager introduces the use case to the tester team. The team should have an accurate understanding of the requirements afterwards. During the review meeting, the tester team presents their test specifications to the System Manager. If any inaccuracy occurs, it should be corrected by the System Manager. This arrangement enables direct communication between the tester team and the System Manager, in order to guarantee the accuracy of requirements interpretation and eliminate anything lost in translation. It also shortens the feedback loop which is essential to achieve continuous delivery. System Managers have closer connection to the

customer side compare to the design department, therefore by communicating with them, NIV eliminates the issue of disconnection with customers.

The Test Specification done by NIV team and approved by System Manager should be completed early in the process, so that they can be used to guide or drive the development of the feature, as seen with the new message event added in Fig. 3 going to the development team. By doing so, the design, development and test departments gain mutual understanding of the feature. When the development reaches the point of Last Software Version (LSV), meaning ready for end-to-end testing, NIV should start test execution.

D. Workshop Evaluation

After the workshop we interviewed the participants to receive their opinions. The answers have been divided into categories to partition the data.

1) Requirement Understanding: One of the changes in the process that was performed in the workshop was to have a requirement meeting directly between the testers and the System Manager (SM). From the participants view

they did considered this to be helpful in understanding the requirements. One participant said that this was very helpful in understanding what the stakeholders wants to achieve. Another mentioned the fact that it helped to clarify the requirements. This would also eliminate issues that could arrive later in the process.

2) Process Difference: These are the differences that the participants described between the process conducted in the workshop compared to the current process. As a whole, all the participants did not consider the changes in the process to be very significant. Most of the activities that were performed during the workshop felt familiar to them and even supported in the current process to some degree already. One participant said that working directly with the stakeholders responsible for the features removed the middleman in form of the Product Owner.

3) Advantages: These are advantages of the process compared to their current process that were expressed by the participants. One participant said that it helped to get a better understanding of the requirements. Another advantage that was pointed out was that by having the tests drive the design, it would give a common understanding of the requirements for both the development department and test department. One participant also said that the SM would have a better awareness of how the system works for the customer.

4) Disadvantage: Possible disadvantages from implementing this process were given by the participants. One disadvantage that a tester mentioned could be that the test specification needs to be more detailed to drive the development. However, he also pointed out that since this more detailed information is added in other documents, those documents might become obsolete. Another point was that the requirement meeting could mean extra activities. A third possible disadvantage related to the second one is that the requirement meeting could be redundant if the NIV testers already have experiences and knowledge of a feature.

5) Feasibility: All of the participants believed that it would be possible to work with the proposed process. One of the testers had a concern that the SM would need to attend so many meetings that it could take up too much of their time. The two testers would implement this process, with reservation that this would impact other departments as well, and would take time to adjust to.

V. Discussion

This research is a case study that took place at Ericsson AB. The majority of the data collection is performed in the company. We hope to generalize the results of this case study to answer our research questions. However as this is a case study of a single company, we need to be aware that the results may be representative to some but not all large-scale companies in the industry. The subject of our research question is set to large scale companies due to the fundamental differences in organizational structures between large-scale cooperation and small enterprises. For example large companies usually have more departments where hundreds of people cooperate to plan, develop and deliver one single product. This can cause inter-departmental communication issues.

We modeled the current process based on not only internal artifacts but also individual interviews and online survey within the NIV department. This means we had the perspectives of the way it should work as well as the way it does work in practice. The diversity of data sources provided us a comprehensive view on the current process. The process model was reviewed by NIV manager. However it was not evaluated in comparison to other model notations.

While we were investigating the current process, we collected NIV members' opinions on the process with open questions. Therefore we received a great diversity of opinions on the advantages, issues and proposed changes (Section IV-B) to the current process. We had reflected some identified issues and proposed changes in our process improvement plan (Section IV-C), for example to improve the communication between departments, to gain better understanding of the requirements and to involve NIV in earlier stage in the process. However not all input we collected are covered due to the scope of this study, for example the teams Ways of Working, the lack of competence etc.

One issue that impacted the efficiency of the process was the unclear requirements. By adding the direct communication between the testers and the System Manager, it will help to clarify the requirements. This correlation between enhanced communication and ATDD was also mentioned in another study by Melnik [19] who found that EATDD (Executable ATDD) helped the software teams to understand the goals of the business. The responses we received from the participants of the workshop were positive about adding the requirement meeting and the review meeting in the process. They claimed that this will helped to provide a better understanding of the requirements.

The evaluation of the workshop (Section IV-D) indicated that the proposal was successful. All the participants agreed that it would be possible to implement the proposed process and also would personally consider implementing it. We could not evaluate the full effect of the process due to the following reasons: i) The scope of the workshop was limited to a portion of the process. The activities after Test Specification were not possible to be included in the workshop due to resource constraints. ii) The evaluation of our proposal is limited to a two hour workshop with three participants. We could only collect qualitative data

which are subjective opinions of the participants. In order to properly evaluate the proposed process, more data points would be necessary, for example a real life project that involves more participants.

The decision to adopt ATDD was based on both the desire from the NIV department to investigate the possibility to use TDD in their process, and from the issues we discovered. We chose to investigate ATDD, the variation of TDD, because TDD would have little impact on the NIV department as it is basically a way to develop new software rather than a method for testing. By using ATDD, the concept of test-first-code-after is taken to the level of acceptance test which is what the NIV department is involved with. The aim of this method is to would help in establishing the understanding of what is to be developed, and help the communication between the different stakeholders in the process [9]. ATDD also fits well with working Lean and Agile which is what Ericsson is working towards.

There are possible drawback by implementing ATDD at Ericsson. In their current way of working, the development department and the NIV department work in many aspects independently. Therefore much of the work can be done in parallel, even if there is still points in the process that have to be aligned. By creating the end-to-end test before development some of these advantages might be lost.

VI. Threats to validity

The selection of interview and workshop subjects is conducted by the line manager. He would select people who he believes have enough experience to provide comprehensive insights. Therefore the selection process is subjective because it depends on the managers opinion which creates potential threats to external validity [20]. We can mitigate this threat by double checking the interviewees employment time at the interview, if he/she is new to the department, we need to treat his/her answers differently.

During the early stage studies we conducted interviews as well as online survey in order to understand NIV members' opinions on the current process. Most of the answers to the "advantage of the current process" states that the process is simple, structured and easy to follow. We have to take in consideration that this can be the result of familiarity of the current process from years of experiences implementing it.

When we interview the employees for their opinion on the current process, some may find obligatory to say more advantages about the current process than to complain the disadvantages of it. Therefore during the interview we must not create leading questions. In order to mitigate this threat, we conducted a trial interview in order to find any question that may lead to bias answers.

The workshop is where we experiment and validate our proposed improvement plan. Due to resource constraints, the workshop consists of only one group of three participants. The data we collect from this workshop are both audio records and three follow-up interviews. The size of collected data can create reliability threat. We can minimize the threat by selecting subjects who have more experiences working in NIV.

VII. Conclusion

The research reported in this paper was aimed at a case study to investigate the issues in the current integration and verification process at Ericsson in order to improve it.

The data is collected mainly at the NIV department in Ericsson through interviews, surveys, artifact studies, as well as a workshop. The variety of the collected data provides us insights to model their current process, identify advantages and issues in the process, propose an process improvement plan, and finally evaluate our proposal.

We addressed the main research question: "How to model the end-to-end test process of a large scale company and identify the issues in the process in order to improve it?" by: i) Modeling the current process from the NIV's perspective using the BPMN notation. ii) Collecting, summarizing and analyzing the issues in the current process, as well as the proposed changes by the NIV members. iii) Proposing a process improvement plan that is inspired by the concepts of ATDD.

We addressed the research sub-question: "How can Acceptance Test Driven Development improve the efficiency of the integration and verification process in a large scale company?" by: i) Proposing a process improvement plan that is inspired by the concepts of ATDD. ii) Experimenting with the proposed process by conducting a workshop. iii) Evaluating the changed process at workshop. The proposed process is tested, however not fully evaluated in this study due to resource constraints. The limited responses we received from the workshop indicates that the proposal is successful. However future research is essential in order to draw a comprehensive conclusion to this research sub-question.

A. Future Work

In order to evaluate the process improvement proposal comprehensively, further research is necessary. The next step would be to implement the proposal to a bigger scale that includes all activities in the process. To validate the proposal further, the process needs to be implemented and run for longer period of time to find out if it will lead to the same result.

We modeled the process with BPMN notation, in future research we would like to apply different types of notations to compare their clarity and coherency.

More case studies in different large-scale companies will be beneficial in order to draw a more generalized conclusion to our research questions.

B. Acknowledgment

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Appendix A

Stage 1 Interview Plan

Purpose of the interview

By conducting face-to-face interview with some employees of NIV, we hope to investigate the current process that's used in black-box integration and verification. Also we would like to get a picture on how much do the team members know about TDD and ATDD, and what's their general opinion about it.

Structure & Misc.

The interview will be semi-structured, which means it would be guided with the following questions however the interviewee is free to add comments regarding relative matters. The interview will be conducted in English and transcribed with a recorder in order to capture qualitative data and to ensure descriptive validity.

Interview questions

Question	Purpose
What is your role in the team?	Different roles in the team might bring different opinions to the process.
How would you describe your current integration and verification process? What are the steps you take?	To get an idea of the current process from the interviewee's point of view.
Can you give examples of different activities in each step? What activity do you take part in?	To get a more detailed description of the current process.
What type of input do you get for the different activities? Any documents or other artifacts?	
Do you use any specific tools for these inputs?	
What type of output do you get from the activities in the process? Who are the intended targets?	
How are do you document the work in the different steps of the process?	
What is the biggest advantage of the current process? (for example which part is efficient and you feel the most comfortable with?)	To understand the advantage of the current process.
What do you think is the problem of the current process? For example during an activity you feel rushed or when you feel the need to wait for the inputs to arrive.	To understand the disadvantage and bottleneck of the process.

What would you change in the current process?	Does the interviewee think changes can be done to improve the process?
How much do you know about Test-Driven Development (TDD) and/or Acceptance Test-Driven Development (ATDD)?	If not, we (the interviewer) will provide them a brief and general definition of TDD.
Do you think TDD and/or ATDD can be applied in your department?	To get their (first) impression on TDD and ATDD.

Stage 2 Interview Plan

Purpose of the Interview

By conducting face-to-face interview with the participants of the workshop, we hope to investigate their opinions about the proposed improvements.

Structure & Misc.

The interview will be semi-structured, which means it would be guided with the following questions however the interviewee is free to add comments regarding relative matters. The interview will be conducted in English and transcribed with a recorder in order to capture qualitative data and to ensure descriptive validity.

Interview Questions:

Question	Purpose
What is your general opinion on the workshop?	How well was the workshop performed.
How does the requirement meeting with SM before TA affect your understanding of requirements?	Find out if requirement meeting have any value to the participant.
Can you name some things that are clarified or not clarified by talking to SM before TA?	
What is your opinion about the review meeting after TS with SM/Testers? How does it affect the following activities (for example TE)?	Find out if review meeting have any value to the participant.
Can you describe the difference between your current process and the one in the workshop?	What's the difference from their point of view
Do you think that the process performed in the workshop could be possible to implement in production?	Subjective feasibility of the process
Regarding the requirement meeting and the review meeting, do you think they are both necessary?	

If it was up to you, would you implement this process change?	Subjective approval of the process
What is the advantage of the process in the workshop compared to the current process?	
What is the disadvantage of the process in the workshop compared to the current process?	

Appendix C

Online survey questions

1. What is your role in NIV?

2. What are the steps in your current verification and integration process (focus on NIV)? Please feel free to add any further comment.

3. What type of input do you get for the different steps? Such as documents or other artifacts, can you give an example?

4. What type of output do you generate from the different steps? Can you give an example of the output? Who is the receiver of the output?

5. What tools do you use to communicate the input and output?

6. What do you think is the biggest advantage of the current process?

7. What do you think is the biggest disadvantage of the current process?

8. In the past few months, did you encounter any case where you did not receive the right input on the right time? If yes, how often?

9. What would you change in the current process?

10. How much do you know about Test-Driven Development (TDD)?

11. How much do you know about Acceptance Test Driven Development (ATDD)?

12. What is your understanding of TDD and/or ATDD?

13. Do you think TDD or ATDD can be used in your current process?

14. If you answered yes to the previous question: How can it be used?

Appendix D

Survey							
	Role	Input	Tools	Advantage	Disadvantage/ bottleneck	how often misaligned input?	feel rushed or wait for input	what would you change?
	Tester	presentation from OPO	Eridoc	Possible to find information	too much paper work 2x	quite often x1		
	Line manager	Documentation (Powerpoint, requirements, use cases) from NDO	Email	less documentation (skip TS)	input doc late, not clear	very often/ 20-35% x3		
		Solution decription	Reqpro	simple, easy to follow and structured x6	time consuming x2	2-3 times x2		
					doesn't get early review of TA	yes x4		
					redundant documentation review			**Less changing in planning**
		customer product information (CPI)	Hansfot	empowerment x2	disconnect to customer (what they want and prioritation) x2	missing/ late input from design org to do TA and TS		**more involvement of NIV regarding what to test**
		Network Impact Report	NIV Portal	well defined test scope		20%-30% times, part of functions are unclear when features are not completed		**2 NIV needs to get involved earlier in the process.**
			Kanban	not so many stages	Long time for STP (setup environment)	twice a month hardware is not prepared in time		**2 Clearer expectations requirements**
			Office	Doc review process with NDO	Too many tools	Input (requirement) changes weekly even daily.		less documentation before testing
				none		No		use one tool for all information

Interviews								
Tester D	Team member, be prepared to take all kinds of tasks	Design unit, EPG dept, MME dept: requirements for new feature.			First time running causes fault		It can take some time to get hold of the person who has the info. Both from other department(design department, system department) and from inside NIV	**We can start tests a bit earlier.**
		M&T, but not very often			setting up test environment takes time		We need time to build up knowledge in order to ask the correct questions	
					Build up knowledge takes time			
Tester E	Tester	OPO		less work for us when OPO acts as interface between depts.	our understanding of the features depend on OPO. Maybe not all scenarios are covered		Both	**Contacet design dept, invite them for discussion before test case development**
		when there is missing or unclear information, we directly contact SM in development team					External dependency, for example when hardware is not ready	
							Because of global sites, can't do anything if there is delay	
Tester A	Team member	Past- feature testing:get high-level description of a task for TA which is produced by OPO and NDO		common backlog is good for prioritization, also good for communication between NIV and NDO	Bottleneck of merging teams in two different environments: lack of competence; new tecnology; cloud environment is not as mature.		Yes sometimes need time to build up knowledge	Change from Sprint to Kanban
	work with testing and process/strate gy work	New- Feature testing and system testing: TA is not done in NIV, therefore TA is an input to NIV			Common backlog requires same competence and environment for all tasks from the teams.			
		New: expect feature testing is done before system testing. Some horizontal tests are done before vertical tests.						
Line Manager B	Line manager	OPO provides requirements to the team. He assign tasks from the program backlog to the teams		Lean and Agile WoW.	Not all processes and departments are really Lean.			Emphazise flow efficiency

	Manage resources and competence	Dialog between NDO and team		Continuous integration and delivery:just started though.	Some teams do not focus on flow efficiency. They lean much harder on resource efficiency			
TCC C	Technical Test Coordinator(TCC) in vEPC program	TA as input for the team	Hansoft	OPO. Responsible to get involved in early study of docs and has full control of the work	Progress is not visualized with the tools we use			**It would be good that the team could work direclty with the system manager**
	Coordinate the vEPC teams and coordinate with Virtual Network Function(VNF) organisation	Solution description	ReqPro					
		Document that EPC program provides	NIV portal					