Performance Based Logistics Information Exchange

Requirements on Information

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Information System Data Flow within Performance Based Logistics

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Abstract

The world is changing. The climate, the world economy and even threats to the society are shifting the last decade or so. Evolving technology are integrating more and more in every day live. The same goes for the Armed Forces, no more traditional warfare but the use of sophisticated technology. The current economy and the everlasting improvement of military technology pushes governments to re-adjust their spending's. Especially the logistics of the DoD has to be more efficient, more effective and overall have lower costs of sustainment of their equipment. Performance Based Logistics is intended to do all that. It is all about wanting the maximum and predictable use of an asset at a predictable, affordable and preferably lowest price. The basic principle is that the customer does not pay for a broken asset but only pays for a working asset; pay for usage. Implementation of Performance Based Logistics comes with a shift of information flow. To be able to sustain equipment, there is an information requirement about the equipment. This thesis proposes an analysis method that is intended to analyze Performance Based Logistics contracts for the availability of information required to conduct Performance Based Logistics. This analysis identifies shortfalls in information requirements, resulting in potential items that have to be resolved during contract negotiations. The analysis model is validated by means of use case scenarios for a land-based sensor.

“I hope that one day armies can be disbanded and humans will find a way of living together without violence and oppression. But until that day comes, we will have to make ideals and human failure meet somewhere in the middle”

General Peter van Uhm, TedX 2011

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CONTENTS

1 INTRODUCTION

The complexity of the (weapon) systems used by Armed Forces is growing. Evolving technology leads to the increase of this complexity and the sustainment of these systems. In this modern day and age the sustainment of the modern systems has to be more efficient and effective. The primary focus has always been the acquisition of technology and systems, but the last decade there has been a shift from buying a system and conducting the sustainment of the system to a long-term (US DoD initiated) program to link performance to acquisition through a concept called Performance Based Logistics (PBL) [1], a concept which represents both acquisition and sustainment.

For the defense industry to offer PBL contracts to a Department of Defense (DoD), information exchange regarding the system under PBL should be addressed. To be able to exchange the needed information, trust of all parties is essential. Implementing a PBL contract is a contract for availability. The active management of the sustainment process (e.g. forecasting demand, maintaining inventory and scheduling repairs) becomes a responsibility for the service provider. As a consequence, the supplier is now incentivized to improve the reliability of systems and reduce the inventories of spare parts. With fewer repairs and fewer spare parts the supplier makes more profit, while from the governments perspective PBL results in optimizing system availability and reducing cost and logistic footprint.

Integration or sharing of information with external parties is not one of the strongest points of a Department of Defense. This is however a subject of change with the introduction of Performance Based Logistics. Of course not over night, but it is certainly an important factor in today's Defense industry.

The interchanging of information will depend on the contracted level of Performance Based Logistics. To simplify the process of analyzing the information requirement and the related information exchange there is a need for a model to facilitate this process. This thesis tries to answer the related questions by developing a general method and to validate it on a sensor under development.

The following sections give a general introduction to the thesis. First the context of the thesis is discussed, followed by an elaboration on the problem. After clarifying the problem the focus on the project is set via the scope and the research questions. Subsequently the validation is explained and this chapter is finished with the contribution and an overview of the thesis.

1.1 CONTEXT

The problem context of this thesis is that of Performance Based Logistics (PBL) and information requirements in relation to data or information exchange. The implementation of PBL in the defense industry is a development that gains more and more ground. Together with potential implementation of PBL contracts, the need for system related information requirements emerges. Information requirements will differ per type of PBL contract.

PBL in general serves as a starting point for this research. The goal is to develop a method for conducting an analysis to identify and address possible information requirements issues for a generic PBL contract.

1.1.1 PERFORMANCE BASED LOGISTICS

Since PBL is the central object for this thesis, a short explanation is given. There are several definitions about PBL, but for this thesis the following definition is used [2]:

> *"An integrated acquisition and sustainment strategy for enhancing weapon system capability and readiness, where the contractual mechanisms will include long-term relationships and appropriately structured incentives with service providers, both organic and non-organic, to support the end user's (warfighter's) objectives."*

In short PBL is the approach to supporting weapon system logistics. It seeks to deliver product support as an integrated, affordable performance package designed to optimize system readiness. PBL meets performance goals for a weapon system through a support structure based on long-term performance agreements with clear lines of authority and responsibility. As said this is a brief summary of what PBL contains, Chapter 3 elaborates more on PBL.

However the focus will not be on PBL itself but on the related information requirements and data exchange of the system under PBL.

To give a more simplified example to illustrate PBL:
The Department of Defense purchases a vehicle. Instead of conducting the maintenance themselves, a Performance Based Logistics contract is signed with a PBL-provider. In this contract there is agreed upon a certain level of availability, say 95% during a complete year. So in essence the DoD pays for available vehicles instead of paying for maintenance. The advantages for the DoD is that they don't have to keep an inventory of spare parts, less cost on maintenance personnel and equipment and don't have to deal with obsolete spare parts (DoD's tend to keep their equipment for 20 years +). On the other hand the PBL-supplier (often the OEM) has a steady income, conducts maintenance in an efficient manner to generate revenue, but carries the risk of obsolescence.

1.1.2 DATA EXCHANGE

Another focal point of this research is on the exchange of information/data. A formal description according to Wikipedia [3]:

> *"Data exchange is the process of taking data structured under a source schema and actually transforming it into data structured under a target schema, so that the target data is an accurate representation of the source data"*

The exchange of data is key for the implementation of the PBL contract due to the fact the PBL-supplier needs information to be able to plan and execute activities to meet the contracted agreements on (for example) availability. Because of the (military) nature of the systems under PBL, the exchange of data is not something to implement without restraints. Depending on the customer there will be variation in the standards for exchanging data. One can assume that there are always restrictions on what is tolerated regarding the exchange of data, storage of data and the use and analysis of the data in information systems.

It can be confusing when the terms data and information are used in the same sentence, therefore a short elaboration; the terms data, information and knowledge are frequently used for overlapping concepts. The main difference is in the level of abstraction. Data is the lowest level of abstraction, information the next level and finally knowledge is the highest level among all three. Data on its own carries no meaning, for data to become information, it must be interpreted and take on a meaning. From the defense domain, data without the context are just characters and digits without any meaning. For this data to become information there has to be a context in order to be able to interpret the data, i.e. take coordinates, writing them down without any form of notation they are plain digits. Add a bit of context and these digits become coordinates (a shift from data to information), but coordinates of what? A ship, an airbase, a compound, troops, an incident? If this last piece of information is added then the information slightly shifts over to knowledge. Because one knows that the coordinates represent a location somewhere in the world and one knows the location of what. Have multiple of these kinds of information and an overview can be created, hence knowledge.

1.2 The Problem

The assignment is formulated by *Customer Services and Support – Service Development* and originates from the need of to have clear view on what the consequences are of offering a PBL contract with regards to information requirements and the subsequent information system data flow. There is a need for an analysis method that will function as a guide for determining the information flow barriers and possibilities, the restraints for implementing such a system and availability of the data after retrieving it from the customer. As an example, a Department of Defense (DoD) buys a radar system from Thales Nederland (TNL), including a contract for availability (PBL). Such a contract for availability means that Thales Nederland needs to perform maintenance, related logistic sustainment processes such as maintaining spares stock level, solutions for obsolescence and improvement of product reliability To make it possible to execute such a contract in an efficient manner, there is a need for (logistic and technical) information. However sharing information about an operational system is not something a DoD (note: more than one nation, Thales has several countries as a customer) easily does. Rules apply for sharing "confidential" or sensitive information and these rules differ per nation and thus per customer. But as mentioned before, some information is essential to be able to execute a PBL contract. Lacking this information would lead to barriers for meeting the contracted agreement on service or availability. To be able to see what information is available and offer possibilities for information / data exchange the assignment is formulated as follows:

Develop a solution for analyzing contractual information requirements in order to be able to facilitate information system data exchange.

1.3 Scope

Thus far the research is quite broad. More focus is needed to get more depth in the research. To create more focus, the following constraints are defined:

- The architecture of the information systems present at Thales Nederland is not part of the research. However the architecture facilitates possible software tooling that may be identified as essential to conduct PBL. As a result the outcome of the research might advise on a set of tooling, but will not elaborate on the standing or future IT/IS architecture of Thales Nederland.
- This thesis is not intended to build a Maintenance Management Information System (MMIS). Best case it will result in advice on essential capabilities for the selection of an MMIS.
- This research is not intended to write new communication protocols for the exchange of PBL related data.
- Logistic cost calculation as a result to information flow will not be part of this research.
- All logistic operations are considered out of scope, only basic PBL related terminology will be applicable in this research.
- PBL related information from the Original Equipment Manufacturer (OEM) to its subcontractors is considered out of scope and therefore will not be part of this thesis. Hence the parties involved are the OEM (PBL supplier) and a DoD.

The research will contain the focus on information requirements according to subject matter experts, identification of possible barriers for information exchange and a proposition for the analysis of contractual information in relation to performance based logistics.

Both the terms data and information are commonly used to refer to the same thing, but as explained before data and information are not the same. Sometimes in a specific context it is more suitable to use information instead of data, just to clarify a point, this thesis is no different. Thus, unless otherwise specified, this thesis will use the term data interchangeably with information.

This thesis is made at Thales Nederland (TNL). The complete research and the coined solution are based upon knowledge and personnel from TNL. It might be that the results are useable for other companies or institutions and therefore Thales Nederland or TNL will be replaced by Original Equipment Manufacturer or OEM (where applicable and possible in the context) to give it a more generic character.

1.4 Research Questions

In this section the focus for this thesis is defined. Concerns discussed in previous sections lead to a single point that creates potential barriers for information exchange, the (IT) communication with the Department of Defense. Because the type of PBL contract determines the complexity of the information requirement, every contract will have its own difficulties regarding information exchange. Eventually there is a need for a method to get a grip on the PBL related information requirements, this leads to the main question:

Can a solution be developed for analyzing contractual information requirements in order to be able to facilitate information system data exchange?

To be able to answer the main research question three sub-questions have been identified. To start it is necessary to know what information has to be exchanged. This leads to the following sub-question:

1. *What is the PBL related required information inside and outside Thales?*
    a. *What are the information needs of Thales and a DoD?*
    b. *What is the prioritization / classification of the data?*

Second which quality is required, leading to the following sub-question*:*

2. *What are the requirements imposed on the data?*
    a. *What is the required data quality?*
    b. *What is the required level of access to the data?*
    c. *What are possible barriers for data exchange?*
    d. *What is the consequence of not meeting these requirements?*

Last how can the information need be enabled, leading to the following sub-question*:*

3. *What are possible solutions to enable the DoD to provide the needed information?*
    a. *In relation to content of the data?*
    b. *In relation to access of the data?*
    c. *In relation to a <u>possible</u> PBL Management Information System?*

1.5 Validation

The solution is validated by means of a use case. This use case is about a land based sensor which will be offered under PBL contract. Testing and validating the method in this way has the advantage that a newly developed system can be exposed to the information requirements on the several level of PBL complexity.

The validation will focus on the following points:

- Data quality
- Effects of not meeting data requirements
- Identifying possible barriers for implementation
- Identification of information system requirements

1.6 Overview

The remainder of the thesis is organized as follows; section 1.7 describes the research approach in detail. Chapter 2 contains the related work and chapter 3 will elaborate on the theoretical background such as Performance Based Logistics, communication and data quality. The information gathering and prioritization of data and related is described in chapter 4, answering the first sub-question completing phase I (see Figure 1). The second sub-question (phase II) is answered in chapter 5, elaborating on the assessment of information. In chapter 6 and 7 cover phase III, answering the third sub-question and building the use case for validation. The main research question (conclusion phase)is answered in chapter 8 and 9. The latter discusses the conclusions from the research including advice on how to handle identified issues and future work.

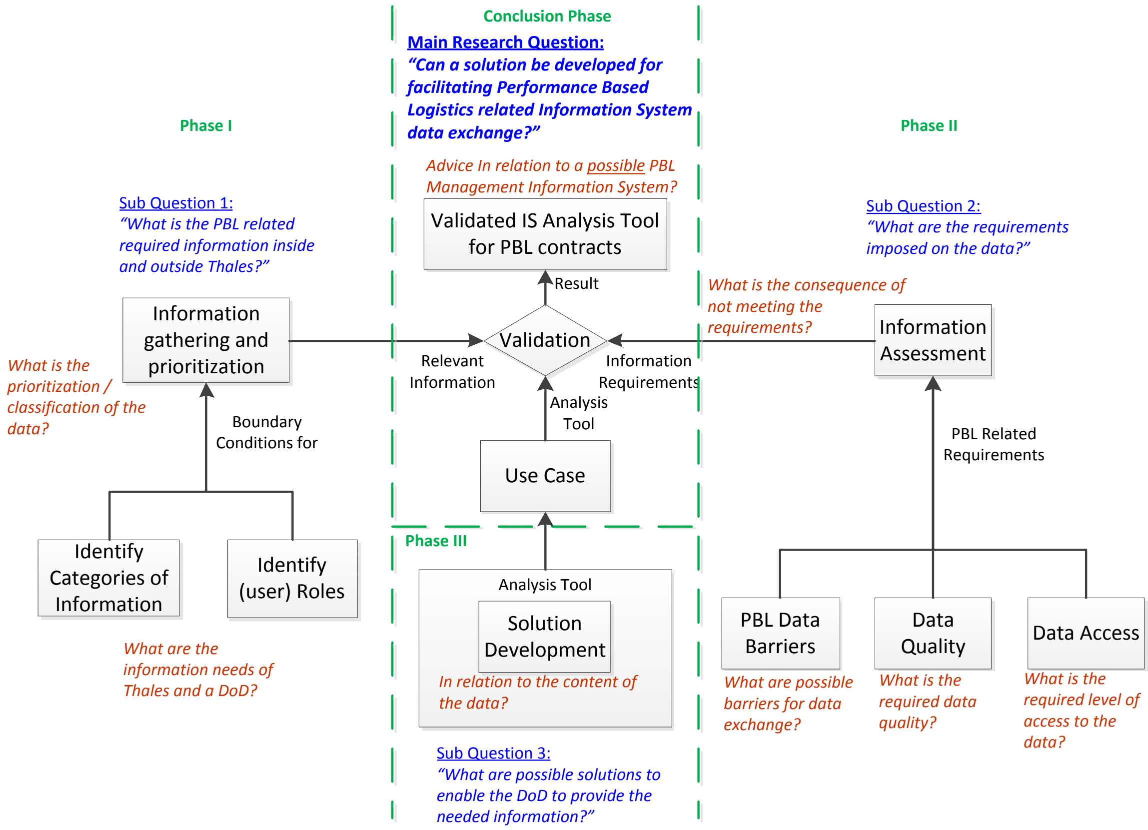

FIGURE 1 RESEARCH DESIGN

1.7 Research Design

The schema (Figure 1) created an outline for the thesis and related the research (sub) questions to the chapters in the thesis. To create more detail, the phases defined in the introduction (Figure 1), are split up in steps. Each of these steps covers a specific stage in the research. To get a better insight in the design, Figure 2 depicts the graphical representation of the research design overview.

The horizontal swimming lanes cover the defined phases (Figure 1), where the columns represent the stages of the research:

- Orientation
- Preparation
- Focus
- Development
- Finalization.

The stages are explained in the remaining sections of this section.

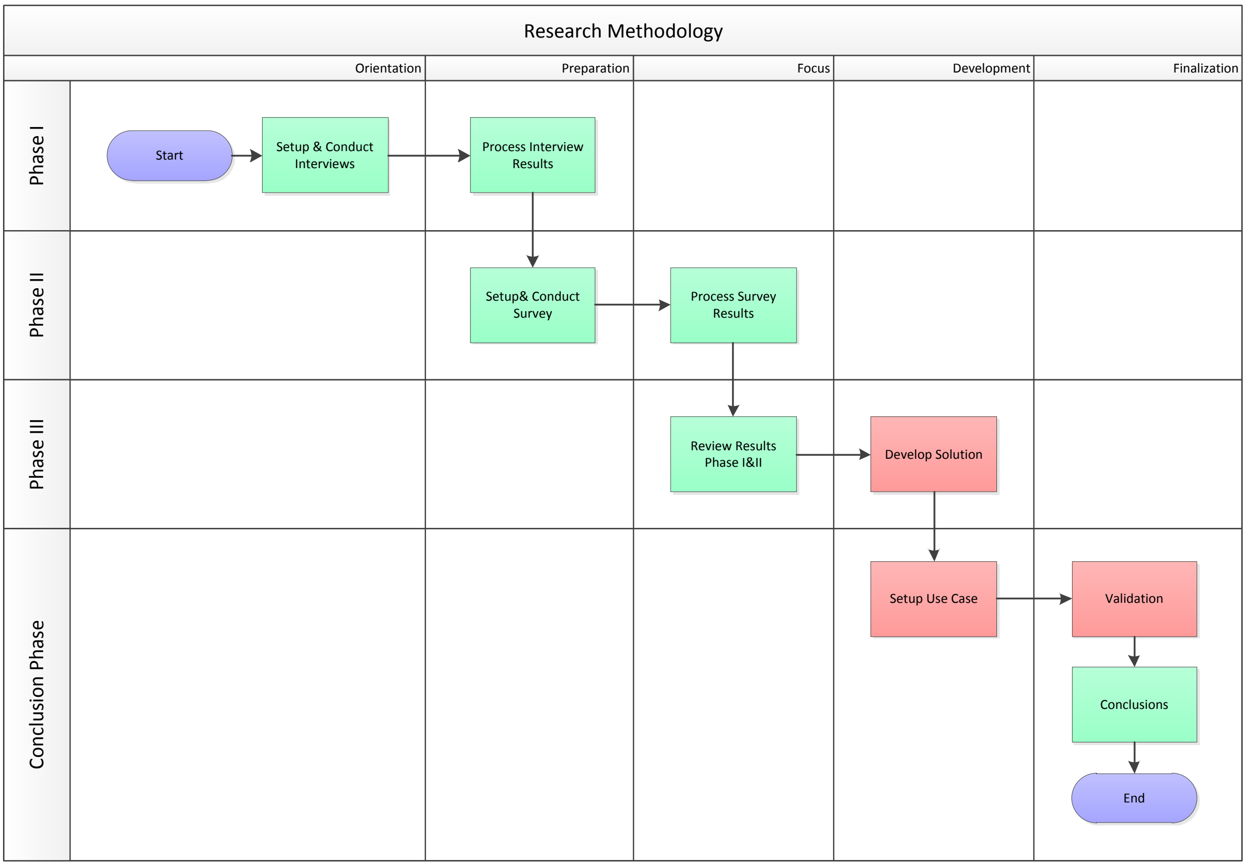

FIGURE 2 RESEARCH DESIGN OVERVIEW

1.7.1 Orientation

To get a better understanding of the dynamics within TNL and of course how the theory of PBL is interpreted by the employees. The steps in this stage seem little, but they are time consuming and essential to get a good starting point for the rest of the research. The basis for the interviews is discussed in chapter 2.

TNL (Hengelo) is considered the audience for the interviews.

1.7.1.1 Setup and Conduct interviews

A set of Subject Matter Experts (SME) relevant to PBL is selected to interview. Relevant SMEs are in this case employees active in logistics, sensor development, and sensor test engineer.

The basic interview is open to get as much information as possible from the interviewees. The general direction and introduction will be the same so that every interviewee has the same starting point. The main question will be: *To your opinion what kind of information is in your area of expertise essential to be able to execute a PBL contract and why?*

During the interview notes will be taken and stored by means of a spreadsheet. The use of a spreadsheet will enable future modifications and selections on notes and general information.

Another element during the interview is to gain knowledge about subjects as Data Quality, Data Access and possible implementation barriers to PBL related information.

1.7.2 Preparation

1.7.2.1 Process Interview Results

The interviews are face to face in an actual conversation. The notes will be entered on the spot in a spreadsheet and thus creating a source of information.

To be able to do the next step, the information collected until now has to be filtered to remove errors and typos. Subsequently doublings have to be identified, because this can point to an information element that is important. Information elements mentioned more than once are marked.

The result from the processing of interview results will be information that the SMEs deem to be important for PBL. Note that at this point no prioritization has taken place in the bulk of information. Also information categories will be identified. The information obtained via the interviews is classified into these categories (without involvement of the SMEs).

1.7.2.2 Setup & Conduct Survey

To prioritize and thus apply another filter on the collected information, a survey is created. The survey (Appendix B) is designed in such a way that the information elements identified during the interviews will be presented to the SMEs in the information categories and scored with *essential, desired* and *optional.* The survey will be done via web based tooling, for which the participants will get an invitation via email.

1.7.3 Focus

1.7.3.1 Process Survey Results

The survey result will give an insight in what the SMEs deem to be the bare minimum on information needed to be able to conduct PBL or execute a PBL contract. The actual scoring of the SMEs will be totaled and the participants will be informed of the outcome thus far.

1.7.3.2 Review Results Phase I & II

With the knowledge of the interviews and survey, an information construction will be developed. This construction will at least contain the information category and priority.

The collected information is assessed and (user) roles are identified, these are of particular interest because they will give an insight on the possibilities on information sharing and possible escalation levels whenever a problem occurs with a system under PBL.

1.7.4 Development

With all information collected in the previous stages, a solution has to be developed. In the case of this research this will be a Decision Tree. The aim of this Decision Tree will be in a relatively simple tree structure to give a better understanding of the consequences of the (none) availability of information, identify choke points or barriers and possible enablers for gaining more information.

1.7.4.1 Develop Solution

For the analysis issue the choice has been made to use the concept of a decision tree. The information categories and identified information will function as input for the basic setup of the decision tree. The tree will be limited in its dimensions to prevent the exponential growth of the tree.

A critical path is the path in the Decision Tree that will enclose all the nodes in the tree that contain the minimal information to be able to execute PBL contracting in a successful manner. The critical path in the Decision Tree will be marked to be able to speed up the analysis of information availability.

1.7.4.2 Setup Use Case

To be able to validate the "solution" or decision tree, the principle of a use case is applied. The topic of the use case is a land based sensor concept. The sensor concept, which is currently under design by Thales Nederland, is ideal to use as the topic for a use case.

A scenario is going to be made that will cover the extremes of land-based deployment and during home base operations of this sensor.

1.7.5 Finalization

1.7.5.1 Validation

With the scenario in place the developed Decision Tree will be used to analyze the information availability in potential contracts, map this information and get an insight in the effect it will have on the execution of the PBL contract. During the validation an attempt will be done to identify possible barriers and potential enablers regarding to information exchange.

The SMEs involved during the interviews and survey, will be consulted to give their professional opinion if the developed solution (hence decision tree) is feasible, realistic and useable.

1.7.5.2 Conclusion

The conclusions drawn during the research will be summed up, but also emerging effects and discovered discrepancies. Further work will be identified in order to continue the evolvement of PBL information sharing between the OEM and the customer.

2 RELATED WORK

During the literature research it became clear that there are enough publications about Performance Based Logistics (PBL) and what the added value is, how PBL can be implemented and as a result an organizational change is imminent etc. But when searching for what the main obstacles are regarding information exchange with a DoD, the result is very limited. Although most providers of software packages / tooling claim that integration with all common systems is possible, it never is explained how communication with a DoD is implemented. In this section related work is summarized that has a relation with my topic of Performance Based Logistics.

2.1 PBL IMPLEMENTATION

To be able to execute PBL in an efficient manner, it is essential to have a proper information system in place. It is possible to guarantee any form of operational availability in a long-term agreement when no accurate information is available, but at higher cost. The need for information is also emphasized by Ngai et al [4] . He stresses that the IT integration in the complete chain is key for a seamless flow and availability of information. The concept of PBL requires information exchange between parties involved, but the actual requirements and responsibilities are laid down in a contract. The first time when a PBL contract is made, this is also called a transition contract. Sols and Johannesen [5] describe these contracts and identify lessons learned. Some of the key lessons are: *what has to change to make it possible, what are the responsibilities (both sides) and what is measured*. The main reason for using a transition contract is the fact that there is a significant way of doing business. Sols and Johannesen defined three blocks; Technical-contractual, Cultural-organizational, Business-political. These three blocks contain several barriers or hurdles, for example; what metrics should be used to measure system performance, how and when should the metrics be measured, do the existing procedures in the organization of customer and/or contractor lack the required flexibility to embrace PBL? And what intellectual and industrial property rights apply? The period that the transition contract should be in place is used to collect data on the complete process. This data collection is only possible when agreed upon in the contract itself.

PBL partnerships require a change of behavior, Wei et al[6] state that; instead of keeping contractors at arm's length at an adversarial relationship, government and industry become active partners and build trust. Ultimately implementation of PBL will require leadership commitment to changing organizational culture and accepting new organizational roles. The tracking of performance data is required to ensure PBL is achieving the expected results of reducing costs and improved performance.

DeVries conducted a research on what enablers and barriers are for effective implementation [7]. In this research he identified barriers and enablers based upon a literature study and one of the most outstanding enablers seemed to be the correct definition of metrics. Hence what do we measure, how do we measure it and who will get the data? In the case of PBL at Thales Nederland (TNL) any information system can be implemented at TNL, but if the system is not fed with data from the systems under PBL the system will not produce the desired information to facilitate PBL. An integration of the complete information system chain from PBL supplier (OEM) to customer (DoD) may be feasible in the distant future, but for now the focus has to be on the basic sharing of data / information in order to enable PBL.

Berkowitz et al [1] stress to standardize decision making based upon (legacy) system output and document performance improvements and lessons learned across the organization, hence a correct management of all collected data from the PBL contract.

Most military logistical systems are complex, Performance-based Logistics demands that the information technology infrastructure to support the logistical system be thoroughly modernized (Baker Spring[8]).

Gansler [9] identified a barrier that has a lot to do with the culture, nicely described by the following example: “ Some military commanders want to “*see*” the required inventory and do not trust a computer based response system”. This highlights how some parts of the military personnel sees the coming of PBL; Just another thing that is going to interfere with my work. On the other side an important enabler for PBL implementation is; an effective IT infrastructure is essential for the required public private integration.

The PBL guide of the US DoD [10] mentions the following item: “The technical specialist must be aware of the following supplier chain flows:

- Physical goods
- Information
    - Shipments are received and tracked. Senders and receivers send shipment information back and forth.
    - Performance feedback is shared between supply chain partners”

Especially the information part is interesting with regards to stability. This is also identified: ”Supply chain partners should be able to establish and share critical information rapidly. As the stability of the supply chain decreases, the product, information, and cash flows will become more difficult to manage”. Hence this also implies that the exchange of information across open communication sources can result in a decrease in stability of the supply chain in relation to the information reliability.

As seen up till now, cultural changes and organizational changes are inevitable when implementing PBL, mostly focusing on the Military organization. However Griffin [11] state: “ PBL strategies are cohesive, adaptable and responsive. They build upon sophisticated information technology support that enables data sharing, a common perspective of the battle space, early awareness of resource consumption and needs, commitment tracking and support for reconfiguration”. This means that the sharing of information is bi-directional, because of the fact that a major part of military operations is sustainment and therefore also an element in operational planning.

2.2 Tooling

There are several software packages, which are or facilitate a Maintenance Management Information System (MMIS), in this section will briefly mention some software packages.

VisionWaves [12] is an MMIS that basically has a dashboard functionality with a representation of key performance indicators, hence at least the basic functionalities of an information system. VisionWaves claims that information system integration is possible; like data exchange via file export, SAP integration, Oracle ERP integration, etc. IT Integration of the VisionWaves software in the existing Thales architecture is possible (probably via middleware), as well as the integration at the customer side. The recurring concern here is the same as the main focus of this thesis, the barriers for sharing a DoD’s (operational) information [13, 14].

Siemens PLM software sees a central role for the Logistic Support Analysis Record (LSAR)[15]. The software is developed according to the military standards like the NATO CALS (Continuous Acquisition Lifecycle Support) Data Model. NATO CALS [16] purpose is to facilitate the integration of digital information for weapon system acquisition, design, manufacturing and support functions. The complete logistic information support is described including usage of databases, again the communication to a DoD is not explained. The Siemens PLM software is not a software package currently under investigation at Thales Nederland.

Another manufacturer of software packages Raytheon has a product that is specifically tailored for PBL, EAGLE MMIS [17]. EAGLE is an acronym for Enhanced Automatic Graphical Logistic Environment and MMIS is an acronym for Maintenance Management Information System (also known as Computerized Maintenance

Management (Information) System CMMS). Also this product emphasizes the need for operational information [1] and suggests that EDI (Electronic Data Interchange) is an option to communicate. However solutions to the common issues like operational security [8, 14] are not described.

All software manufacturers mentioned in this subsection (there are more without a doubt) are unanimous about the need for asset information to be able to execute PBL. One can conclude that there is enough tooling to facilitate the PBL process, the key here is the identification of the enablers for data exchange with a DoD. How different the countries may be in their issuing of rules for (operational) data security, it is essential to offer options for exchange data. These options can provide solutions for data exchange and create alternatives for a data exchange issues.

2.3 Data Exchange

It became clear that the data responsibility, forms of exchange of data and information system integration are barriers for implementing PBL. The complexity strongly dependents on the level of maturity or PBL level. Hence the more contractor support (see Figure 3 PBL Spectrum) is contracted, the more the responsibilities of maintenance and (operational) system availability will shift to the contractor. Subsequently the shift of responsibility will lead to an increase of information availability or access. Doerr [18] identified measurement issues and pinpointed the same issue that is raised here:

"Measurement issues are endemic to the relationship between commercial sector vendors and the DoD. From the point of view of measurement, the best PBL candidates are those with external markets for services, and clear outcomes that are easy to relate to mission objectives."

There is a NATO standard for logistic support information systems: NATO CALS Data Model (NCDM). The NCDM is intended to support exchange of logistics data between different operations and applications [16]. It will need further research to determine if NCDM is useable for data exchange between TNL and a DoD. Up till now TNL stores the Logistic Support Analysis Record (LSAR) according to the mil-std-1388 (NATO standard of CALS).

Giannotti [17] suggests EDI as a means of data exchange. However the one of the outcomes of research done by Scala [19] is that EDI requires high initial capital expense and EDI requires high volumes before benefits are attained. These higher overhead costs are the result of the use of the EDIFACT standard (United Nations build standard: Electronic Data Interchange For Administration, Commerce and Transport). If the EDI suggestion by Giannotti is based on the more modern XML usage, than the overhead will be substantially lower. JSON is unlike XMLEDI not commonly used as a format for data exchange. However open formats for data interchange like XML (Extensible Markup Language) and JSON (JavaScript Object Notation) are more recent and future-proof, something that could be very important because of the life span of military assets.

However information exchange has its limitations Li and Veenstra [20] state that the value of information varies and the use of information may even be detrimental, too much information is as undesirable as too little. Hence there have to be some thoughts about what is essential to know in the PBL process.

3 Theoretical Background

This chapter will elaborate on the theory of Performance Based Logistics and related topics that will be used in this thesis. Technologies that are common in today's market will not be part of this chapter

3.1 Performance Based Logistics

Taken into account that there are a lot of different opinions for the same subject, there has to be a choice how to define the concept of PBL. In this thesis the definition of PBL from Berkowitz [2] is used:

> *"An integrated acquisition and sustainment strategy for enhancing weapon system capability and readiness, where the contractual mechanisms will include long-term relationships and appropriately structured incentives with service providers, both organic and non-organic, to support the end user's (warfighter's) objectives."*

Figure 3 depicts the dynamics of a PBL environment. When implementing and executing PBL the responsibility of sustainment shifts from the owner (organic) to the PBL-provider (contractor or OEM). This shift means that it is rather difficult to define all scenarios upfront, the remaining conditions are determined during contract negotiations. In other words the contract is rather fluid and has only boundaries in the extremes. It is important for the PBL provider (or OEM) to determine its critical path for a PBL contract in order to get the right information in the right amount at the right time to be able to execute a PBL contract in an efficient and effective manner.

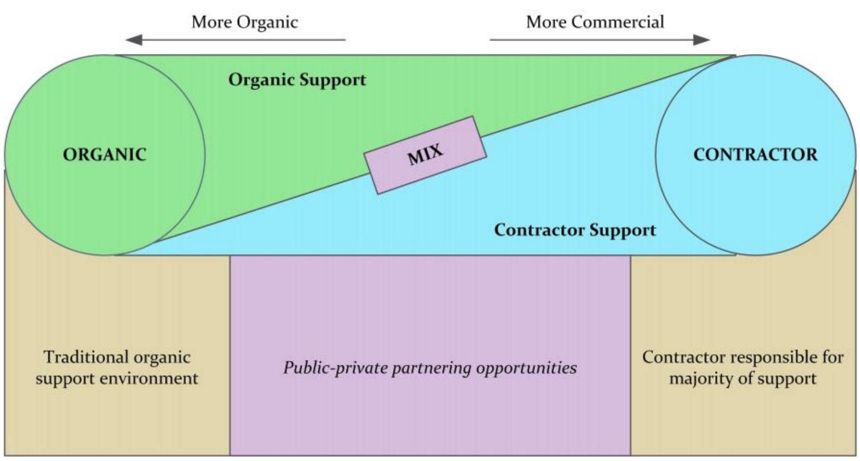

Figure 3 PBL Spectrum

In simple terms PBL is a contract for availability, where the customer pays for an operational system. This means that the sustainment of the system shifts form the customer to the OEM, including all the risks. The risks include costs for keeping stock, lead-time for repairs or supply of COTS products from sub-contractors and obsolescence (a spare-part or article becomes a non-deliverable), but also the training of operators and maintenance personnel.

As of now OEM will be used during the course of this thesis to represent the entity that executes the PBL contract. In the literature the OEM also can be referred to as PBL supplier and contractor. The main focus of the PBL information exchange will be on the DoD and the OEM. The information exchange between the OEM and its subcontractors will not be a part of this thesis.

Zooming in on PBL there is a rather extensive information requirement for the OEM. A standing support or maintenance organization gathers and uses information of the supported systems. The OEM evidently needs the same information. Besides the basic information like configuration settings, hours of operation etc., defect reports, log files and so on are required by the OEM in order to facilitate product improvement and cost reduction in order to keep the sustainment costs as low as possible. With this information serves the purpose of prediction and optimization of support needs.

In principle the information need can be divided in the following categories:

1. Use(operational) information; this is information that is collected during use [21], hence Dynamic Preventive Maintenance data. This is all data that can be used to trigger maintenance on a system. Examples are hour counters of (sub) systems, deployment period (the time frame that the complete system is deployed). The second purpose of this information is (as mentioned above) to conduct statistical calculations for prediction and optimization of the sustainment. The third purpose is product improvement, which will lead to less system failure and more gain for the OEM.
2. Configuration information; how is the system build and of what components or subsystems, the system breakdown. This information has a close relation to use information because of the fact that the hour counters are related to a specific item [22].
3. Planning information; when will a system be deployed, what kind of spares are needed to ensure the sustainability during the deployment of the system. Execution of all pre- and post-deployment checks, and as a result when will the system be available for maintenance [22, 23]. Planning information also includes supply/stock information. Intrinsic to PBL the OEM takes responsibility for the spares. This implies that the spares in stock at the location of a system (this can be an (air) base or a ship) are also the responsibility of the OEM. Thus the OEM has a requirement or even better the responsibility to know what the stock levels are at the different locations.

Availability planning is a normal process for a DoD, this planning will indicate when what equipment must be operational capable. This Material Availability Plan (MAP) is an essential source of information for a maintenance unit. The MAP is used plan the workload for a maintenance unit throughout the year. The MAP will have all essential equipment listed and when it must be available for the unit to be able to train and conduct assigned operations (i.e. deployment). Creating a MAP is a DoD responsibility

It is in the OEMs interest to have information to the maximum extent in order to be able to predict or prevent failure and ultimately to keep costs as low as possible. Besides these costs, an OEM will face penalties whenever the contracted availability is not met. These penalties are settled during contract negotiations and vary from contract to contract including the availability level. PBL contracts can be arranged in many different ways from loose with only the end goal and some boundaries set to very ridged with the same end goal but very detailed regulations of what is allowed. Whatever the contract restrictions, boundaries or agreements are, the need for information does not change. The parties have a common interest regarding to what information will be exchanged and it is not only the OEM that requires information. To be able to monitor the PBL process the DoD also has an information requirement such as available systems, availability of support etc. all key performance indicators (KPI).

All in all the information requirement is more than information of the system alone; it is also the planning information that forms a boundary condition to be able to execute the contract efficiently. Lacking this information does not imply that the contracted availability is not feasible it is merely more costly.

3.2 Information Flow

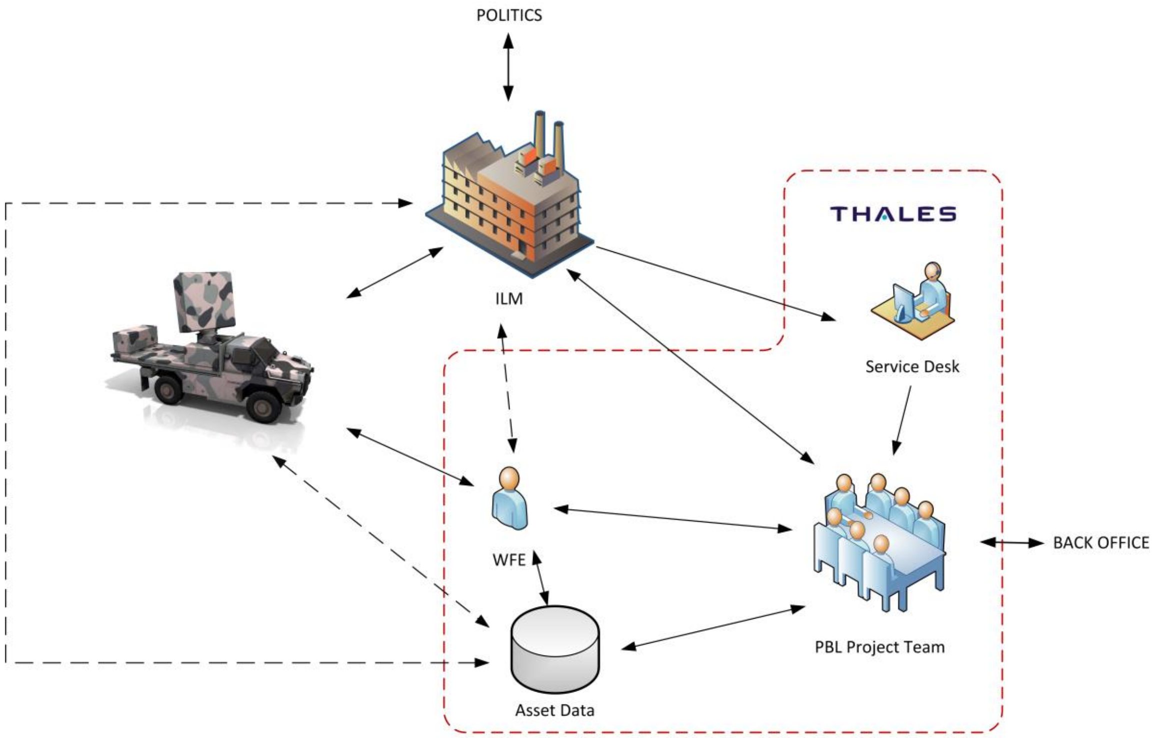

FIGURE 4 INFORMATION FLOW SCHEMATIC

To be able to visualize the information flow that is inherent to PBL, it is useful to create a general overview of the parties involved. At the highest abstract level one can distinguish only the OEM (or PBL provider) and the customer (DoD), zooming in to a lower level more detail becomes visible. The OEM (Thales Nederland in this case) has several entities; (1) the service desk. (2) The PBL project team, (3) the Water Front Engineer (WFE).
The Water Front Engineer is the engineer on site. (4) A Defense Material Organization or Intermediate Level Maintainer (ILM) and of course the asset and asset data. In this thesis the theory is mapped over the general situation at Thales Nederland (Figure 4).

As seen in Figure 4, there are several lines, dashed and solid. These lines represent the information flow within a PBL contract. The solid lines represent the information flow that is likely to be implemented. Within the OEM organization there is an information flow as well, most of the time this exchange of information is related to product improvement or support to the main sustainment process that is contracted.

Although the sustainment of an asset is contracted via a PBL contract, the OEM has to keep in mind that the owner of the asset also has an information requirement. This information requirement is a result of the fact that a DoD has to be able to verify asset status, i.e. is the asset available or what preparations have to be done to be able to support the asset for a longer period of time in case of a deployment. Besides this information, it has to be considered as a possibility that a DoD wants to be able to view the technical status of its asset.

To explain the flow of information in Figure 4; a dashed line represents a “possible” demand for information from a DoD, i.e. access to the asset (or systems) data, this requirement originates from the idea that a DoD wants to be able to access the technical system status. However this is something that has to be agreed upon during contract negotiations. Thales Nederland (TNL) has the need for information to be able to execute the contracted availability in an efficient and effective manner but this “need” for information is mutual. A

DoD wants to have the confirmation on the availability of essential spare-parts of a system (under PBL) at the start of a mission. The second dashed line from the system or asset to the DB represents an option to automate data transfer to the DB / IS and the other way around, i.e. a full system integration, this is a topic for further research. In order to keep PBL feasible, it is important that the basic information exchange functionality is in place.

The fact that an information dependency is mutual once a contract has been signed is already mentioned before. Figure 5 represents the relations and dependencies that emerge during a contract. Thales is the OEM and the customer is a DoD (the crest is from the Dutch DoD, but it could be a DoD of any nation). The OEM supports a customer by maintaining the product that the DoD owns. This support comes at a price and boundary conditions such as information availability and access. On the other hand the customer requires (status) reports from the OEM about the health of its asset(s).

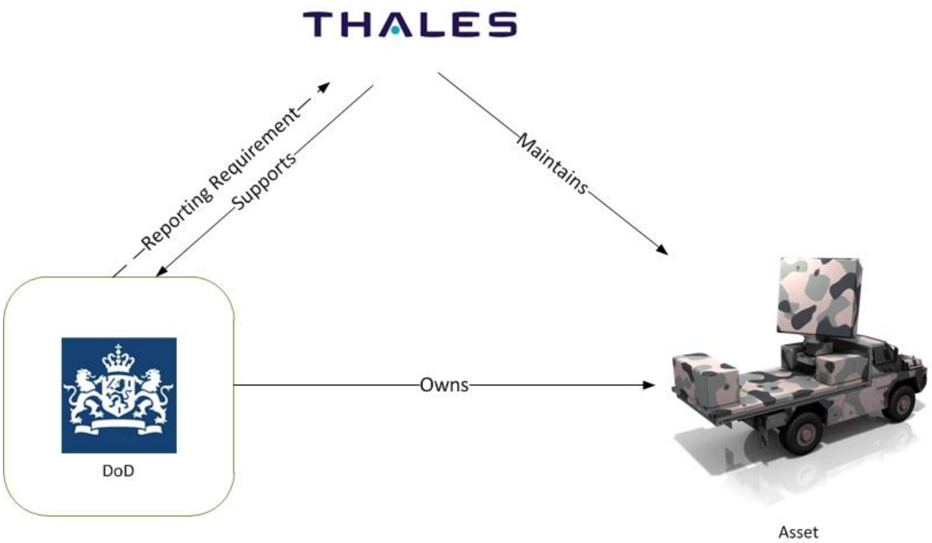

FIGURE 5 INFORMATION FLOW RELATIONS

3.3 MAINTENANCE MANAGEMENT INFORMATION SYSTEMS (MMIS)

There are sufficient Maintenance Management Information Systems (MMIS) available on the market, even MMIS that are specifically tailored for PBL. A MMIS is also known as a Computerized Maintenance Management System (CMMS) or Computerized Maintenance Management Information System (CMMIS). These names for the same system will be encountered in the literature, but the function is the same. In this thesis the term MMIS will be used. What does a MMIS do? Information in an MMIS is intended to help maintenance workers do their jobs more effectively (i.e., determining which machines require maintenance and which locations contain the spare parts they need) and to help management make informed decisions (i.e., calculating the cost of machine breakdown repair versus preventive maintenance for each machine, possibly leading to better allocation of resources). MMIS data may also be used to verify regulatory compliance.

A lot of MMIS are web-based so that there is easy access to the information. Of course there are also vendors that produce MMIS that are LAN based (hence only client access). All MMIS information is stored in a database. In case of Thales Nederland (TNL) an assumption is made that all received information, internally and externally is stored in the same locations as is done currently and that this information is accessible by means of an MMIS.

A typical setup of MMIS software includes the following job-elements:

1. Work orders
   Scheduling jobs, assigning personnel, reserving materials, recording costs, and tracking relevant information such as the cause of the problem (if any), downtime involved (if any), and recommendations for future action. Typically, the MMIS schedules preventive maintenance automatically based on maintenance plans and/or meter readings.
2. Asset Management
   Recording data about equipment and property including maintenance activities, specifications, purchase date, expected lifetime, warranty information, service contracts, service history, spare parts and anything else that might be of help to management or maintenance workers
3. Inventory control
   Management of spare parts, tools, and other materials including the reservation of materials for particular jobs, recording where materials are stored, determining when more materials should be purchased, tracking shipment receipts, and taking inventory.
4. Safety
   Management of permits and other documentation required for the processing of safety requirements.
5. System integration
   MMIS packages often link to enterprise software and process control systems.

The job-elements mentioned above organize the information requirement that an OEM has when executing a PBL contract.

During this thesis there will be no specific advice on a MMIS, at most a set of requirements that must be met by candidate MMIS software. In the following chapters there will be an analysis on which information is needed and how it is prioritized

3.4 NATO CALS Data Model

NATO CALS Data Model (NCDM) defines a common set of data definitions that can be used to achieve consistency of interfaces at the information level without requiring standardization of hardware or software. The role of the NCDM is to standardize content of a life-cycle repository for defense technical information with the objective that Armed Forces with different Information Technology infrastructure, e.g., different hardware and software platforms, can make use of the same technical information.

The NCDM consists of a core model with several subsidiary models. The purpose of the core model is to provide a high-level definition of various views of a product; the product as specified, as designed and as built. The subsidiary models are:

1. Product configuration;
2. Failure Analysis
3. Task description
4. Technical documentation
5. Logistic Support Analysis
6. Supporting models; models to capture information about approvals, personnel, etc.

Merely because of its existence it is mentioned in this thesis. However at this time there will be no further support of the NCDM and version 4 will be the last one. With the knowledge that there will be no more support, the option to use and or apply the NCDM seems no longer valid and therefore will be dropped as an option to use as a model for data exchange.

3.5 Data Quality

Data quality states something (as the name suggests) about the quality of the data. To be more specific, data quality (DQ) is the accuracy of the data presented by an information system and how it is in the real world [24]. The data quality of a system would be a 100% if the representation of the data by the information system is perfectly in line with the real world situation. It is not realistic to say that an information system has a DQ of 100%.

As opposed to what one would think the real concern with DQ is not the level of perfection of the data, but that the quality of data in the information systems is accurate enough and consistent enough for the users to make decisions. So if the latter is the case and users can make well-founded decisions based on the data, all additional effort to bring the DQ as close as possible to 100% is in fact wasting resources. Data which is fit for use by data consumers is also known as high-quality data [25].

According to feedback control system (FCS) theory whenever a system tracks the real world, there must be a mechanism to synchronize the data in the information system with the situation in the real world. Two things have to happen for data in any database to track the real world:

1. Someone or something (person or an automatic sensor) has to compare the data views from the system with the data from the real world.
2. Any deviations from the real world have to be corrected and reentered.

To fully understand the FCS model in an information system see Figure 6. Data is entered in the system, processed resulting in an output and simultaneously stored in the database. This loop maintains the database and represents the real world as accurately as possible. Reflecting the FCS model onto the situation of TNL, this means that whenever data is received from the customer, there has to be a comparison to the information present in the database. An update of the data in the system is necessary to represent the real world situation. This is essential because more than one department within TNL will use the information in the database. A mismatch with reality will result in a less precise action based upon the data in the system.

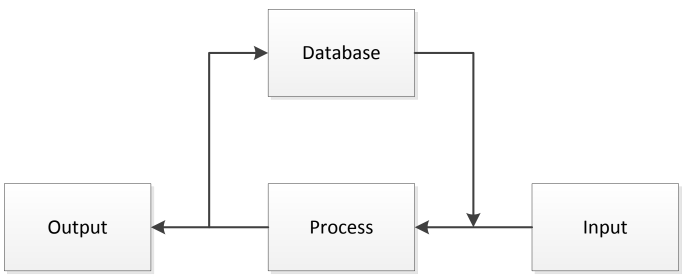

FIGURE 6 INPUT-PROCESS-DATABASE-OUTPUT MODEL

It is common to collect large numbers of unused data elements [24], with the idea that someone might have a use for them somewhere in the future. If an organization is not using stored data, than over time real world changes will be ignored and the quality of data in the system will decline.

To make a point, storing data for use is essential for an information system to work. However if the idea is to store data just for the sake of having it at ones disposal, it will result in poor DQ and thus a possibly wrong (business) decision.

One approach is to conceptualize the processing and storage of data as a data manufacturing system [25]. Within a data manufacturing system three roles are identified: data producers; data custodians; and data consumers.

Roles	Characteristics	Tasks
Data producer	People and other sources that produce data	Data-production processes
Data custodians	People who provide and manage computing resources for storing and processing data	Storage, maintenance and security
Data consumers	People or groups that use data	Data utilization and potential data aggregation and integration

TABLE 1 ROLES CHARATERISTICS AND TASKS

High quality data consists of four categories [25](see Table 2): Intrinsic, accessibility, contextual and representational aspects

DQ Category	DQ Characteristics
Intrinsic DQ	Accuracy, Objectivity, Believability, Reputation
Accessibility DQ	Accessibility, Access security
Contextual DQ	Relevancy, Value-added, Timeliness, Completeness, Amount of Data
Representational DQ	Interpretability, Ease of Understanding, Concise Representation, Consistent Representation

TABLE 2 DQ CATEGORIES AND CHARACTERISTICS

Besides the overall meaning of data quality, an opportunity emerges for data selection in relation to the information requirements per PBL level. First of all only select and store the information that is required and not the information that “might be useful” for “possible analysis needs”, too many ifs. In addition the category accessibility can be used for identifying possible solutions for the availability of data from an asset.

3.6 Formats at Thales

As mentioned before in this chapter, to be able to execute a PBL contract it is necessary to have information about the system under PBL contract [2, 23]. Besides the logistic information of the system under PBL (planning and spares information), there is the system information itself. The system information includes log files with information about sensors, hour counter, fault codes, etc. let’s say the current situation or health of the system. Hence this information is needed for maintenance activities and product improvement.

To be able to collect this kind of information, a maintenance application is running on the sensor called the Maintenance Center. Furthermore due to the complexity of the sensors build by Thales, test procedures are integrated so that it is possible to check the functioning of the system. These tests are called Build In Test (BIT). Information from the Maintenance Center can be viewed by means of a Maintainer Terminal, an application running on a laptop and interfacing with the Maintenance Center via a direct connection (RJ-45).

The results of the BIT’s as well as the information from the Maintenance Center (i.e. hour counters, etc.) are logged. All information logged by the system is bundled into a single file, the Event Log. The Event Log is a binary file, double compressed in order to keep its size as small as possible.

All BIT results are binary, in order to prevent the customer from reading these files. The philosophy behind this decision is that there are a lot of notifications that can be interpreted wrong due to the complexity of the system resulting in a situation where the customer asks about failure notifications from the system that are meaningless. Some information is human readable, i.e. defect reports are stored in XML.

In general the majority of the information is stored in a binary format, only readable when using tooling. Thus the information that is to be exchanged on system level from the customer to the OEM is to be marked as binary.

3.7 Conclusion

Performance Based Logistics is a concept that has been coined by the US DoD to reduce costs and keep the level of availability as high as possible, overall reduce the footprint and make the logistic support and sustainability more efficient and effective. For a PBL provider (in this research the OEM) to be able to provide the expected level of available operational capacity one can assume by rule of thumb that the same information now required by the standing maintenance organization is required by the OEM to be able to perform their tasks in an efficient manner.

For parties to be able to exchange information trust is essential. This is not only trust from the customer to the OEM, but also the other way around. At least these boundaries should be well contracted so that there is no misunderstanding. In short mutual trust and agreement or “marriage”, in combination with available technologies on the market, is an enabler for PBL implementation.

4 COLLECTING INFORMATION

To get an overview of what information is needed, interviews with personnel of different disciplines are conducted. The disciplines are i.e. logistics engineering, technical engineering, service desk and service level managers.

This chapter will elaborate on the concept of information, the roles in the information exchange process, the information categories and which priorities are set on the availability of information.

4.1 INFORMATION CONSTRUCTION

To ensure a common view about the information, it is necessary to have a common ground. This viewpoint has been confirmed in interviews and discussions. Thus there has to be a general concept for this thesis regarding the "construction" of information.

So what can be said about information? The information has to be exchangeable via a medium, it says something about a system that is under PBL and as a result the information has a priority. So the main elements (in random order) that are defined are (see also Figure 7):

- Medium
- Category
- Priority

4.1.1 MEDIUM

This part of the information indicates the possibility of information exchange via a communication channel. With the current speed the technology develops, it is not unthinkable that in the near future new communication technologies will be introduced. Thus listing the possibilities will be limited, without excluding the possibility that future communication technologies can and will be implemented.

Hands-on is actually the most simple but also effective manner to retrieve the information from a system. The WFE can download the data directly from the system or from a hot swappable drive. Note that this possibility only covers system information.

Telephone call: when other options fail, simple information like fault messages can be communicated. This is an emergency measure.

VPN: direct communication to exchange (larger amounts of) information, it also enables real time information.

Repository, FTP, etc.: more asynchronous exchange of information with the advantage that the system does not need to be online to retrieve needed information. The downside is that this communication medium excludes real time information exchange.

Mail; simple way to just send (parts of) information retrieved from the system under PBL contract.

Telemaintenance; this is a process on its own. It implies a form "secure" communication technology like VPN and remote maintenance of the system by means of resetting, software updates, etc.

One possibility that is not listed here is the integration of ERP systems via middleware. Later on in this thesis there will be more elaborated.

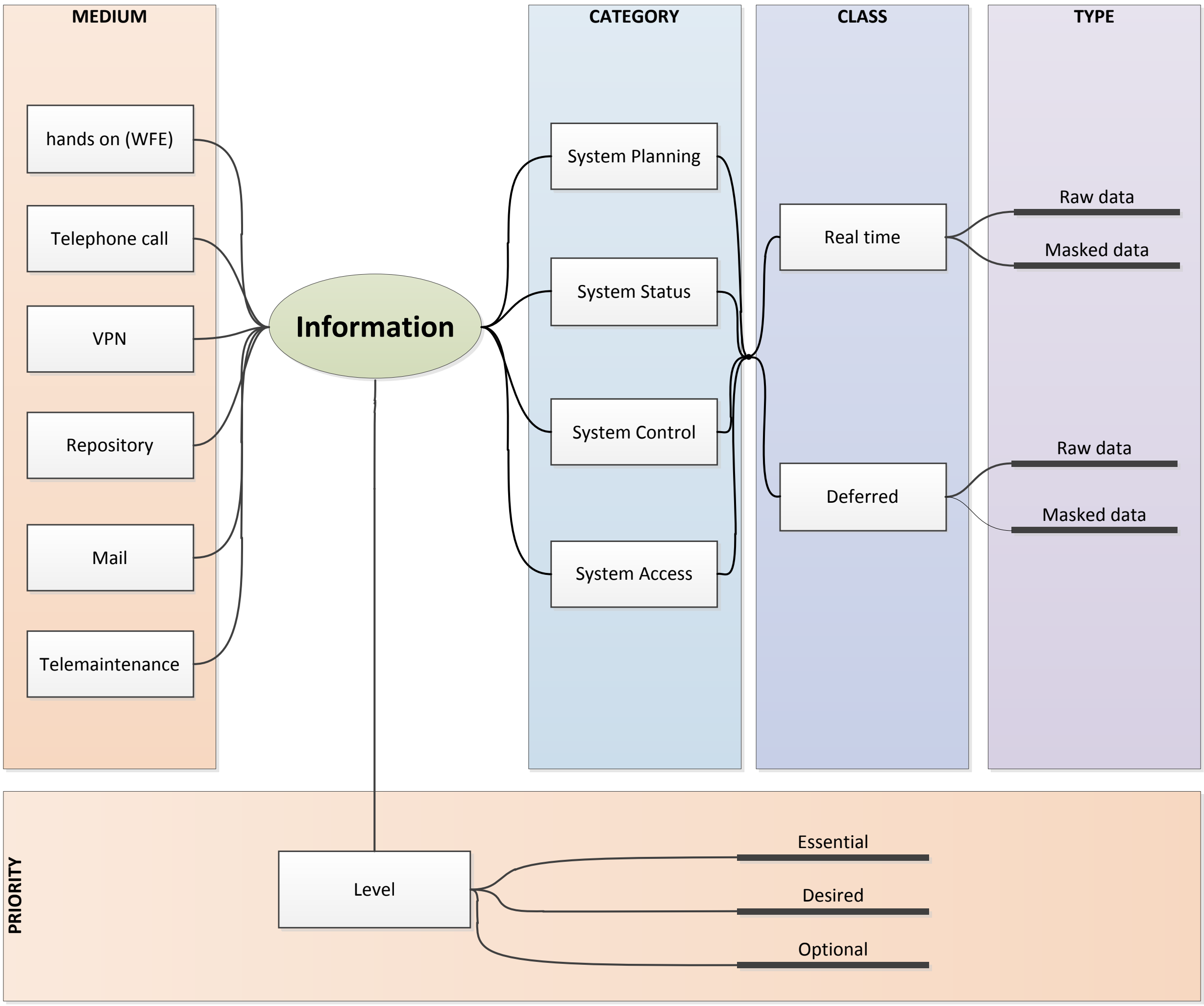

FIGURE 7 INFORMATION CONSTRUCTION

4.1.2 Category

To be able to categorize information, first the information categories have to be determined. Four categories are identified (Figure 8): System planning, System Status, System Control and System Access. These categories result from the first interviews where a need for planning of resources was identified, information about the system is needed, external actions want to be applied to a system and finally who has been working on the system [2].

System Planning contains all information needed to be able to conduct maintenance on the system under PBL, hence all preconditions.

System Status is all current and past (logged) information about the system under PBL, i.e. Configuration, Running hours etc.

System Control; These are all proceedings that <u>can</u> affect the system under PBL. Note the emphasis on can; the system is accessed but when there is only monitoring of the system (remotely of course) it does not influence the system itself. An example is that when a system has issues and the local technicians cannot figure out the problem, an engineer from the OEM can remotely login and view the behavior of the system. In this way there is access to the system, but there is no change.

System Access is logging of physical access of the system (opening of doors and cabinets) but also the access of the system electronically. This category can also contain the allocation of access rights to the system.

PBL is more that system information alone (confirmed by an SME). There is also the need to know the location and status of maintenance significant items (MSI) or spare parts. These spares can be on several locations i.e. the OEM, DoD or an external supplier. However the focus of this thesis is the information exchange between DoD and the OEM (bi-directional) and therefore the external parties are considered out of scope.

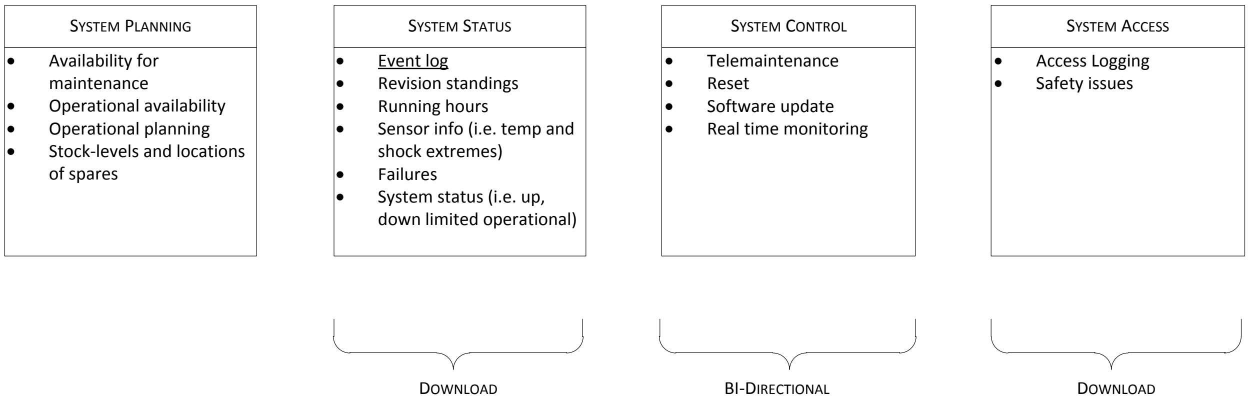

FIGURE 8 INFORMATION CATEGORIES

4.1.3 PRIORITY

Information has a certain priority. To be able to conduct PBL some information is more important than others, thus every information element has to be scored. During this research there are three options for scoring the information priority: Essential, Desired or Optional. With Essential meaning that this information is absolutely necessary for the PBL process, Desired states that the information will be used and absolutely supports the PBL process but if it’s not available the process will be hampered but not stopped. Lastly Optional, this is information that is useful and could support the PBL process but it will not damage the process in anyway if it’s not available. One could say it’s nice to have.

If there is no prioritization on information there is no way to determine on what part of the information is really important. Basically the message is send; “We must have all information”. But as stated earlier before there is also such a thing as too much information and that is just as undesirable as to little or faulty information [11]

4.1.4 CLASS

The class indicates if the information element is preferred to be real time or deferred. The preference is set during the interviews

4.1.5 TYPE

The type indicates if the information should be raw data, hence all of the recorded data or that a selection of this information would suffice.

4.2 User Roles

Figure 9 represents a graphical overview of the relations between user roles and the form of communication amongst these roles. The user roles are based upon personal experience (DoD side) and a possible way of conducting the PBL process at TNL. In total five roles are identified:

1. Thales (OEM)
    a. Service Desk
    b. PBL Project Team (including PBL manager)
    c. Water Front Engineer (WFE)
2. DoD
    a. DoD Authority
    b. Organizational Level Maintenance (OLM)

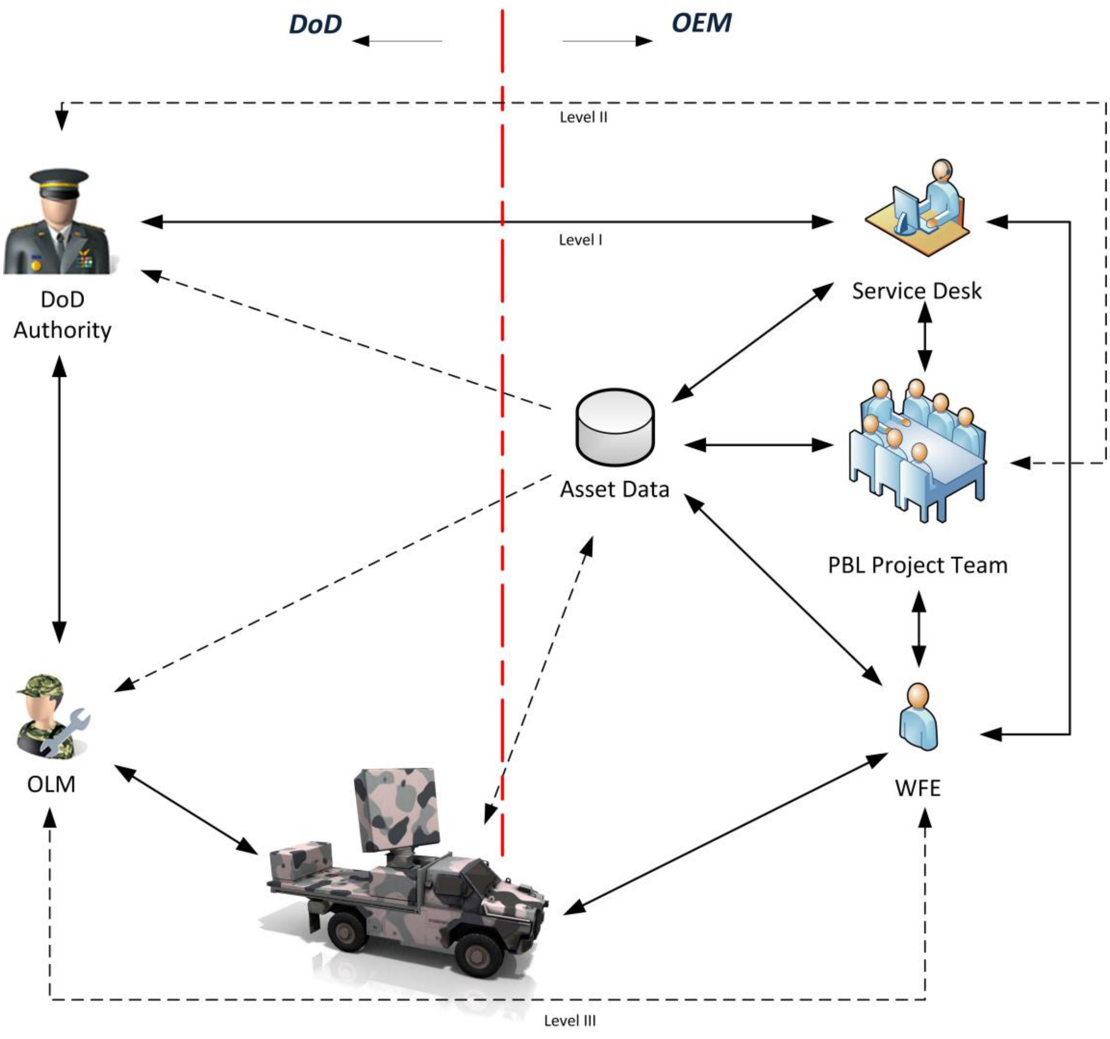

FIGURE 9 USER RELATIONS

The next sub-sections elaborate more on the roles. Before going to the sub-sections more explanation about Figure 9 is appropriate. Besides the user roles the figure also represents the communication, in whatever form, between the user roles. This means that this communication can be via telephone call, but also via mail or file sharing. Hence it is all information and to be precise information about a system that is maintained via a PBL contract. Eventually all information should be stored in a database, most likely at TNL.

The solid lines represent the communication between roles on day to day basis. The dashed lines represent possible information needs or flows and of course the arrows depict the direction of the information. For example the dashed line from the database to the OLM or DoD authority represents the need from the customer to be able to see information regarding to asset status, this can be needed for operational planning or confidence building.

Also visible are the levels I, II and III. These levels represent escalation levels, level I represents normal day to day operations, there is an issue that the DoD authority reports at the service desk or any other request. At level II there is an urgent issue that requires attention from the PBL project team, therefore there is direct contact with the PBL project team bypassing the service desk. On the spot communication regarding a formal (reported) issue that has to be resolved immediately is represented at level III. The OLM and the WFE communicate to solve the issue. Note; there will be also informal communication on the spot between the OLM and WFE on a day-to-day basis (this is not represented in Figure 9).

Not a role, but never the less worth mentioning is the resources, skills and tools that an OLM needs to perform his job. These pre-conditions are also supplied by the PBL provider and are more important when there is a need for registration of these preconditions like in the aviation industry.

4.2.1 Service Desk

The service desk is the first contact for customers regarding all kinds of issues including technical problems and complaints. In normal circumstances the service desk should function as a single point of contact to the customers, hence the front office.

4.2.2 PBL Project Team

The PBL project team is responsible for the execution of the PBL contract. This implies that they are also responsible for planning the maintenance of the system under PBL contract. As a result the PBL project team will have more interests than only the technical status of the system. The availability planning is important in order to be able to schedule servicing on the system and reserving own resources to be able to conduct the servicing of the system. The composition of the PBL Project Team can vary per project or contract phase, due to the different expertise's that are needed.

4.2.3 Water Front Engineer

The water Front Engineer is the onsite technical representative of the OEM. The WFE has knowledge of all systems access to the TNL resources (i.e. tooling and OEM engineers) and will be able to train the OLM on the job. The WFE will be responsible for the onsite support and sustainment of the system under PBL

4.2.4 DoD Authority

The DoD authority can consist of several entities, like a systems manager or a complete department dedicated to the sustainment of the system under PBL up to a resources planner or an ILM. This structure will vary per DoD (of a Nation). Like the PBL project team, the DoD authority can change due course of life of a system. Hence in the implementation phase high-level involvement will probably be the case, whereas when the end of life (also known as ELOT) of the system is approached there is no need for a high level representative.

4.2.5 Organizational Level Maintenance

The Organizational Level Maintenance is the onsite technical representative of a DoD. This can be one person or a group of persons depending on the complexity and deployment purpose of the system. When a PBL contract is in place the training of the OLM is a responsibility of the PBL supplier, in this case TNL. The OLM will conduct the maintenance of the system during the deployment of the system.

4.3 Information Categorization

To record information that is collected during the interviews an excel worksheet is built (see Appendix A). Every information element mentioned by the interviewed SME also result in completing the remainder of the columns: Element; Category; Class; Deferring Time; From; To; Sys/DB; Contact.

- Element: This is the name/description of the information element itself.
- Category: The information category, this will be filled in after the interview.
- Class: Can the required information be deferred or not.
- Deferring Time: if the class indicates that the information can be deferred, this column represents how long it can be deferred according to the SME.
- From: The source of the information, who (which role) initiates the information transfer.
- To: The receiving end of the information transfer.
- System/DB: The location where the information should be stored. At this time this is the location as is, hence the same location where the information is stored now.
- Contact: The name of the interviewee (SME)

After every interview the received information elements are categorized. This is done by determining what the information is about. Hence if the information is about preconditions for the system like planning, spare parts etc. than the information element belongs to the category System Planning, if it is about the system itself then it belongs to the category System Status. When the information element involves some kind of remote connection to the system, then the information element belongs to the category System Control and if it's about access logging then it belongs to the category System Access.

4.4 Information Prioritization

When the information requirements are listed (see Appendix A), the prioritization has to take place. On average most SME's agree upon the information requirements, however sometimes there will also be a deviation of this average. Typically this deviation is a subject that correlates with the SME's area of expertise [26] and therefore is very specific. To be able to create an overview of information requirements with a higher level of abstraction (hence less details), the listed information requirements have to be prioritized.

In case of this research the prioritization is done via an online survey. The survey is made using a tool available at TNL, *Thales NL Enquete tool* by LimeSurvey. For this survey questions are made (see Appendix B), that propose an information element and ask the question if this information element is *Essential, Desired* or *Optional.* At the end of each series the SME can leave some remarks, in order to give the SMEs an opportunity to reflect on their choice. Not all information elements recorded during the interviews will be used, because of possible doublings or similarities. This is explained to the SME's prior to the start of the survey. Sending this survey to all SME's asking for their opinion will score the information elements.

As mentioned before the outcome of the survey will yield a priority of the information elements (see Appendix C) where the lower the score the higher the importance. Subsequently the most important identified information elements are selected for use in the next step of the research the information assessment.

4.5 Conclusion

To conduct PBL there is a need for information. However this information requirement is different at any level of the organization. It is important to see what information is actually necessary to be able to support the process of PBL without the burden of an information overload. Detailed information to discover product impurities or faults is essential for product improvement, but to support the main process of PBL it is a desired piece of information not essential. Again too little information and too much information leads to an inefficient process and errors [11].

5 INFORMATION ASSESSMENT

The information requirements gathered during the interviews give a direction to what kind of information is needed to be able to execute PBL contracts. Also notes made during discussions with SME's during the course of the research gave an insight of what is needed regarding the quality and availability (hence the access) of information.

5.1 DATA QUALITY

Referring to the theory in chapter 2, Data Quality (DQ) can be divided into four categories:

- Intrinsic Data Quality
- Accessibility Data Quality
- Contextual Data Quality
- Representational Data Quality

Results from the interviews shows that one of the most important items is the choice between real-time information and deferred information. The second important item is the accuracy completeness of the information. The accuracy belongs to the category intrinsic DQ whereas Timeliness and Completeness belong to the category contextual DQ.[25] The requirement of real-time availability of information implies that there is constant access to the system (Data Access will be elaborated on in the next section).

During the interviews the amount of data (size), accuracy and timeliness were frequently a topic of discussion. The engineers want to have all information possible about the behavior of the sensor, preferably real-time. Technically it is possible to transfer this information real-time, but the transmission will consume a considerable amount of time due to band-with (also very expensive) and interruptions of the transmissions. The interviews and later on the survey prioritized the information requirements (Appendix A and Appendix C).

In detail DQ is an important element in the complete information chain. If the information is not correct or in time, the logistic system that supports PBL can fail. Thus what is acceptable in terms of DQ? How much delay can information have without losing the DQ it needs? According to the SME's the timeliness of the information, depending on the requirements of the (logistic) engineers this time can vary from immediately to 6 months.

Regarding to completeness here can be reflected to the event log (EL). It might not be possible or even not permitted to send and / or receive large amounts of information. Therefore it could be helpful to select a specific part of the EL. This selection than could be send to the WFE or TNL location. Again this depends on the situation the system is in and the ability and permission to access the information of the system. More elaboration on the access in the next section.

A pitfall here is the focus on information that has to be derived from the system. The information in the system itself, hence the event log, is not the only information that is needed to be able to support the system from a PBL perspective. Without going into the logistic details, the information can be divided into 3-4 categories (Figure 8); System Planning, System Status, System Control and System Access.

The information that can be put under the category System Planning has to come from the customer itself rather than from the system (obviously also from the customer). However this information is crucial to the logistic preparation[23]. To be able to plan maintenance activities, resupply of spares, change of spare stock etc. information is needed about the availability of the system, hence the Material Availability Plan (MAP) is the starting point for the PBL contract. Planning is essential because sources are limited. When information for general preparation is not available (hence the MAP), one can only make preparations based upon historical figures. Whenever the system is (relatively) new, the historical information is not available and therefore this can be an issue. Especially in these cases it is essential that the customer is willing to share the planning information. To be brief, planning information is an important source for the PBL provider to be able to make a preventive maintenance schedule. The planning information is a part of the complete PBL information requirement of a specific system. Therefore the principle of DQ applies here as well. The provided planning information has to be relevant and complete. Relevancy is important here because the planning information provisioned by the customer should be limited and / or direct related to the system under PBL, all other planning information is not relevant. Too much (not relevant) information can only pollute the chain of information [11].

During the research all requirements are documented in a spreadsheet (Appendix A). This spreadsheet also contains notes about if the information can be deferred (time shift) or that the information has to be direct, the latter implies real-time. When applying more focus on the necessity of real-time information, it became clear that only during troubleshooting remote monitoring of a system can reduce cost / unavailability. A note here is that if there is no WFE or technician on site that can solve the problem, the only solution may be to get someone on site.
The majority of information can be acquired during pre- and post-deployment checks, defect reports (sharing of information) and for example (masked) event logs. The relevancy of the information after a mission is still guaranteed because it is the most current information available. The maintenance center of a sensor has the ability to generate a defect report. Because the defect report is a simple report (PDF format) that contains details about the malfunction, it is easy to send from the customer to TNL.

The use of pre- and post-deployment checks satisfies the main (logistic) information requirement. An additional advantage is that there is no real-time connection with the system once it is deployed.
One has to take into account that when there is an opportunity for a complete download of an event log during pre- and post-deployment checks that there will be a considerable amount of information of that single system. This information has to be stored into the standing information system architecture within TNL. If PBL contracts are signed with more customers and / or more systems, the information load will grow drastically and with it the need for storage.

What is needed in terms of data quality? Information can be masked, deferred and so on, this influences the data quality. Availability of all information real-time will guarantee the highest level of data quality, but as mentioned before this is not always necessary (see also Appendix A). The most important thing is the synchronization of the information. To ensure that all parties work with the information that represents reality an update of PBL information should take place whenever the possibility arises, this includes home base activities and post-deployment checks.

5.2 Data Access

Data access is the most sensitive subject for a DoD. Depending on the nation and their intentions, goals and assignments to outsource logistics, they will be stricter or not. Either way the access to information by an external party will always be an issue for a DoD, it creates vulnerability in their network. Ever since the stuxnet attack on the Iranian Nuclear plant [27] external system access became an even more hot topic.

The basis of PBL starts with the contract. This contract contains the agreement on the level of availability for the designated system. The access to data and the exchange of information are pre-conditions to efficiently and effectively execute the PBL contract. Data access is about the ability to access the information present on the system under PBL. This is not planning information but system status and system control information.

The availability of (system) information influences the efficiency of the PBL contract. The more information is available about the system, the richer the history will be. This information can be used by logisticians to make calculations about Mean Time To Failure (MTTF) and Mean Time To Repair (MTTR) [28]. Also the engineers can use the information for product improvement and re-design.

There are three options identified for obtaining the information needed for PBL.

1. Remote access to the system under PBL. Regardless of the location of the system connection will be made via a variation of carriers and the information will be downloaded from the system (sensor), with or without human interference (pull).
2. Sharing of information by the customer, again regardless of the location of the system. In this case the customer will send the information to the PBL supplier via a communication means. The customer has full control over what is send to the PBL supplier (push).
3. On site download. This is the most pragmatic option. The waterfront engineer (WFE) is on site of the system and makes connection with the system (in a controlled environment) for a download of the event log. Another way is to swap a hard drive with a verified blank one to ensure that there is no access to the system itself.

Resulting from the interviews, the minimum access to PBL information is the Dynamic Preventive Maintenance (DPM) data, because this data will reflect on the state of the system. Whenever predetermined values are met, maintenance is needed. More specific this data contains all system information related to maintenance such as; hour counter, temperature sensors, configuration settings, defect reports, etc. DPM data does not contain information about malfunctioning of the system, opening or closing of cabinets and so on. Reflecting this on the options identified, one can say that it is the simplest to access this information on site via pre- and post-deployment checks.

If the latter is not possible, then one has to wonder if it is feasible to have a PBL contract in place when it is not possible to access a system under controlled circumstances. Conducting maintenance activities will be very difficult when there is no access to the system.

Figure 10 illustrates a possible sequence of events that can occur with a system under PBL contract. This timeline may shed some light on the different terms used and the dynamics of sustainment.

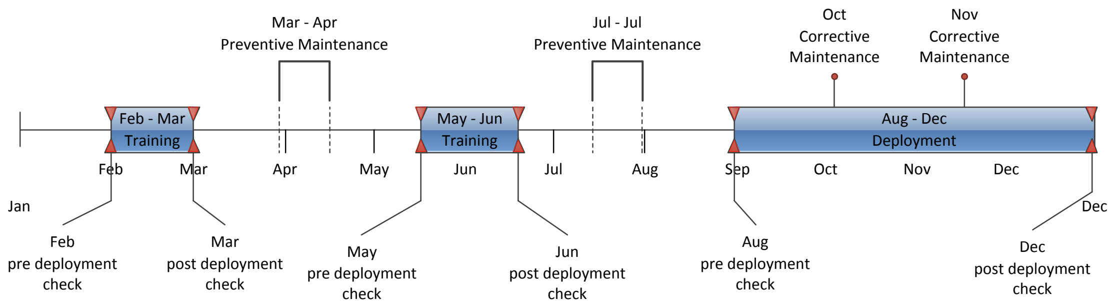

FIGURE 10 TIMELINE

5.3 Barriers for Data exchange

It is no secret that a DoD is not eager to share information. But faced with cutbacks most DoD's do not have a choice other than to search for more effective solutions for logistic support of their systems. Forced into a position that leaves no other option than to share information with third parties. However this does not mean that systems will be wide open to everyone that conducts business with a DoD.

Without a doubt there are more barriers than mentioned in this thesis. All depending on the nationalities, cultures and government policies. These barriers will impose all kinds of restrictions on the exchange of information, from mail to applied protocols and so on. However when a DoD is considering a PBL contract, one can assume that there has been some thought about the exchange of information. Not only in terms of system related information, but also (mission) planning and reports demanded from a potential PBL supplier.

Thus the main barriers for data exchange will be limited to Cyber Warfare and Exchangeable Information.

5.3.1 Cyber Warfare

Cyber Warfare is an emerging topic. Actually Cyber Warfare is something that the most DoD's are nervous about. To ensure that computer guided and / or controlled systems on any kind of platform, air, naval or land is not compromised or contaminated by hacks or other kinds of malicious code, the systems are completely locked from external contact (Air gap). For example the Dutch DoD is preparing by building a Cyber Command and also released a Defense Cyber Strategy [29]. This also emphasizes the importance of cyber security for the DoD of a nation. The Dutch DoD will not be the only nation that is preparing for Cyber Warfare and therefore it is an important barrier to take into account.

The worst case scenario is already mentioned; all systems are locked from external communication, this to minimize the risk of an attack on (weapon)systems [27].

Because of the rapid development of new techniques and hardware, cyber threats become more and more a point of concern. It is not only the software or physical contact of a computer against a system that poses a problem, it is also the hardware that can be malicious [30].

Keeping in mind that Cyber Warfare is an issue, still the customer and the PBL supplier need to decide on a way to exchange information

5.3.2 Exchangeable information

Besides the threat of Cyber Warfare there is another barrier; exchangeable information. Again the repetition of the message that information is and will be a sensitive topic for both the industry and a DoD. Not only the vulnerability of a system for DOS attacks or stuxnet attacks is an important item, also the kind of information that can be exchanged.

The industry has information regarding a system that is considered intellectual property. This is the information about a system that is unique and forms the core of that specific system (series). It is evident that the OEM (or industry) is not likely willing to share this information, just because of the fact that this is the basis of the main product. Mostly this will be technical information and information about how the system specifically works.

A DoD has classified information. This information covers several areas of military field of operation. Because it covers more areas, the information referred to in this chapter is about the system and its use. Keeping the latter in mind, not all DoD's are willing to expose their doctrine. Besides the doctrine, utilizing an event log can also mean that with regards to temperature, humidity, altitude hours of operation of a system and even GPS information will be logged and therefore the whereabouts of a military force could be deducted. Thus even solely the system information can be sensitive information for a DoD.

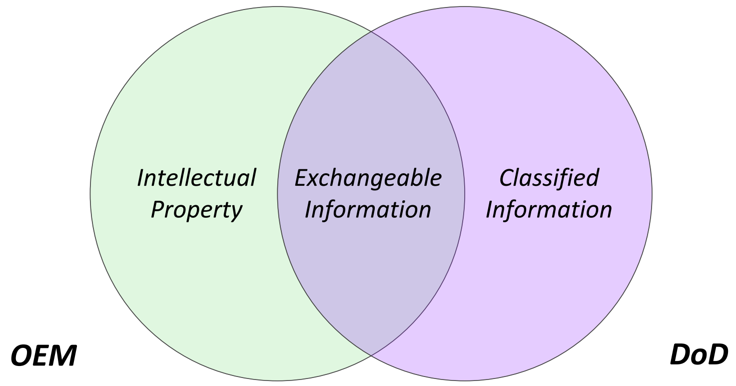

FIGURE 11 EXCHANGEABLE INFORMATION

Again to be able to conduct PBL information is key. Thus it is important to determine which information is exchangeable. Figure 11 depicts the relation of the exchangeable information regarding a system under PBL. A prerequisite here is not the available techniques for information exchange, but trust. Some parts of information can be indicated by a DoD as sensitive, but the same information can be essential for product improvement, hence the content of the event log can be a topic of discussion. There has to be a mutual supported agreement about what can be exchanged and what not regarding system information. If this is not defined clearly prior to the start of the PBL project, it will lead to discussions on what is acceptable and what not. Eventually the focus needs to be on the middle part of the diagram, the exchangeable information.

5.4 Conclusion

Taking all observations made during this chapter into account, one can conclude that the most information can be retrieved by conducting pre- and post-deployment checks. The current situation in terms of configuration settings and Dynamic Preventive Maintenance data covers a lot of areas of information need. During deployment (and even at the home base locations) information can be exchanged via defect reports. Although the latter may not be sufficient when it comes to failure analysis and troubleshooting. If it is not possible to transfer the complete event log (EL) during deployment, it should at least be possible to make a selection of the EL so that the size and mission history are no longer subject to discussion.

When information becomes available in the form of event logs, defect reports, spares stock levels etc. a flow of information from the customer to TNL will emerge. This information needs to be stored and managed. At this time the assumption is made that the information generated from PBL contracts will be stored in the same location as it is done at this time.

Synchronization of information is important. Thus whenever a system is at home base or it returns after a deployment (of any kind), there has to be an update of the information available at the PBL provider. Especially when the PBL provider internal process depends on the input of PBL information, the provided information must be as accurate as possible.

TNL (or OEM) needs to identify up front which information can be shared for example in reports and event log information with the customer.

All points considered raised in this chapter, one can conclude that a minimum of information availability has to be met, this minimum is the Dynamic Preventive Maintenance data. Lacking the remainder of the information will have consequences for costs and availability of the system.

6 DEVELOPMENT OF A SOLUTION

After the gathering of information from experts and the information that the research has yielded, a simple model of the problem can give a better understanding of the situation.

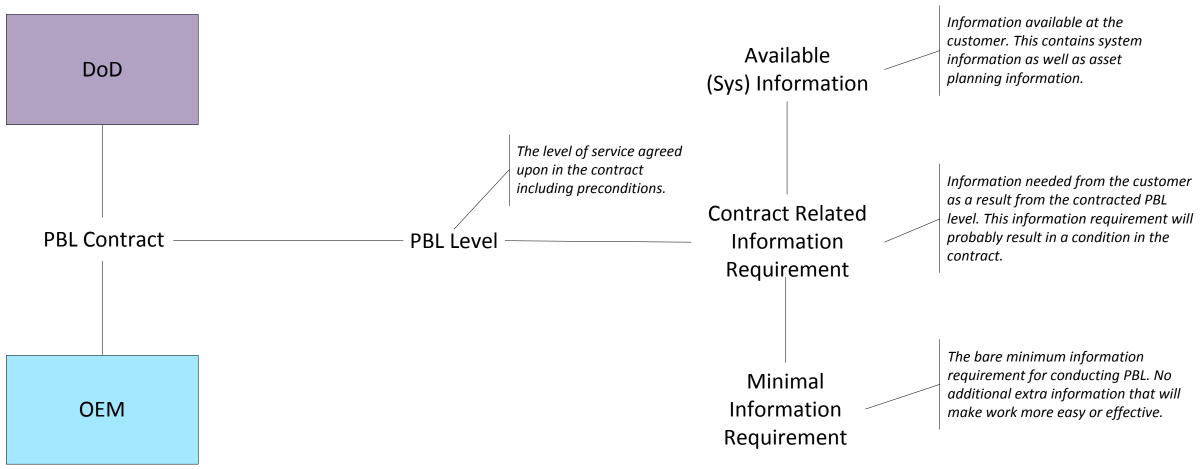

FIGURE 12 CONCEPT FOR INFORMATION SOLUTION

There are two players involved, the customer (DoD) and the PBL supplier or OEM (TNL) (see Figure 12). A PBL contract contains an agreed level of availability of the system. In order to be able to provide sustainment of the system, a minimal information requirement arises. The level of availability (or PBL level) recorded in the PBL contract requires a certain amount of information. The customer has the information about the system subject to the PBL contract. Now the problem area becomes clear. The customer is willing to release some information to the PBL supplier, but this information does not meet the information requirements of the PBL supplier. In this chapter a possible solution is coined for analyzing the initial information availability prior to the PBL contract in order to determine short falls in this information availability.

6.1 DETERMINING THE INFORMATION REQUIREMENTS

In the previous chapters research has been done to determine the information requirements. Depending on the complexity of the system under PBL, the information requirement will change. The more complex a system, the more information about the system is necessary to ensure the sustainment of this system in an effective and efficient manner.

If it was up to the technician all information should be available real-time, preferably with direct access to be able to tweak the system. Of course this is not a realistic situation, merely of the following reasons:

1. A DoD will not allow continuous access and monitoring of it systems by an external party. There are several reasons, but the most important is security.
2. The cost of keeping a communication channel (satellite, HF, etc.) will take on enormous proportions. Depending on the systems under contract there will be an increase of strain on the available bandwidth (and thus limiting the bandwidth for operational communication).
3. Continuous data gathering without a specific scope will have a negative effect on the data quality [24]. The data that will be gathered must be used to ensure that the information stored at the OEM databases will correspond with the real world.

Appendix C is an excel sheet that contains the survey results in the form of prioritization, hence which information elements are important and required to be able to execute the contract in such a way that it is feasible. The information with the lowest score on a scale from 4 to 12 is the most important.

This table is a result from the conducted research, but a note is in place; The information requirements are generic although typical for TNL. This means that if the system under PBL has a high complexity this will result in a more elaborate information requirement, merely due to the composition of the system.

As a result from the survey the main items for PBL information are:

1. Identification, equipment, line replaceable units information, etc. Hence configuration information
2. Operating hours of the different systems, sensor data, etc. Hence Dynamic Preventive Maintenance (DPM) data.
3. The complete set of recorded system data. Hence the event log
4. Defect reports from items that had to be replaced (LRU).

Thus whenever there are preparations prior to contract negations, the available information provided by the customer has to be analyzed if the elements mentioned above are present. For this thesis the analysis of information will be done by means of a decision tree, primarily because of its ease of use. The next section will elaborate on the decision tree and why certain choices are made.

6.1.1 The idea

A decision tree is a relatively simple way to represent information. The principle is easy to understand and to interpret. After a brief explanation most people are able to understand the decision tree. Besides if an analysis build by means of a decision tree, this analysis can be further developed by adding statistical information to the tree or other decision support information. Thus a decision tree can be simple at startup but can become complex once it further develops.

Because of the ability to represent information in a simple way, the idea is to setup a tree that covers the information categories and the main information elements and requirements within that category. The elements represented in the decision tree have to be limited because of the grow behavior of the decision tree. This precaution is intended to limit the dimensions of the tree.

When the decision tree is build, a critical path can be defined representing the minimal information requirement. Conducting an analysis of available PBL information using the decision tree yields into an insight where the available information deviates from the critical path. This deviation can result into actions to obtain the required information or a higher price for a PBL contract (due to higher risk for the PBL provider).

6.1.2 The Dimensions

The dimensions for the decision tree (DT) are based upon the information categories (Figure 8). PBL information is not limited to only system information, also spares and the “status” of the spares including their location are essential when maintaining such a high tech product like “military” sensors. However at this stage of research the inclusion of tracking and tracing of spares will not be a topic for further elaboration.
The planning information is also a part of information not directly related to the system information, however for planning and preparation purposes this is an essential piece of information.

Because of the nature of planning information, hence the introduced Material Availability Plan or MAP, it is available or it is not. Thus this part will form the first dimension of the decision tree.

To build the decision tree these dimensions are chosen:

1. **System Planning**
   This dimension is the availability of planning information regarding the system (MAP). More specific it is the planning that indicates in which parts (or blocks) in a year the system is planned for deployment (in whatever form), hence the system is not available for the sustainment process. The remainder of the year, where no time is reserved the PBL provider can plan its sustainment activities.
   System planning is covered in the point A, B and D in the decision tree (Appendix D).
2. **(System) Access to the information**
   This dimension is a bit ambiguous in relation to the information categories. But in essence this is not the registration of access information of the system, it is the ability of access to the system or the information. The latter implies that the access is restricted, which means that the information is available but only a selection under specified conditions.
   This dimension is covered in the points B→C and D→E in the decision tree (Appendix D)
3. **System Control**
   This dimension is about the choice in the way the system information will be available. Arriving at this point already implies that the access is restricted, hence bound to conditions. Again this point in the PBL process represented by the decision tree will lead to different courses of action by the PBL supplier.
   This dimension is covered in the points C.1, C.2, C.3 and E.1, E.2, E.3 in the decision tree (Appendix D)
4. **System Status**
   This dimension contains leaves, hence the end of the decision tree. It is still possible to choose a slightly different path although these are minor differences.
   This dimension is covered after the point C.1, C.2, C.3 and E.1, E.2, E.3 in the decision tree (Appendix D), thus traverse further through the remainder of the tree up till the leaves.

Thus four dimensions are defined, each with their own reasoning every dimension goes into more detail about the available information. Every dimension has an influence on the contextual data quality[24, 25]. Hence is the information complete, is it on time and is it relevant. Even in case of a remote connection the amount of data is important due to the "limited" connection options.

Due to the fact that the first dimension simply asks if planning information is available or not, the decision tree splits and both branches will be identical. The reason for the branches being identical is that the planning information is an important piece of information, but it does not say anything about the system information. Thus regardless of the planning information, the steps about system information have to be taken.

Deployment options are deliberately left out of the tree as a dimension. The nature of deployment can differ (as will be elaborated on in the use case), there are in principle three main types:

1. Home Base: This is the peacetime situation and location for the armed forces. This insinuates that the unit(s) will be on the base.
2. Training and exercise: simulation of combat situations. This is a repeating cycle to get a unit up to a certain level and keeping it there.
3. Deployment: a real deployment.

If these deployments are implemented in the tree, it will grow almost exponentially in size. As a result it is no longer readable and therefore useable for information analysis. Thus if a contract needs to be tested on several deployment options, for each option the decision tree has to be applied for the analysis of the information (see also chapter 7).

6.1.3 The Critical Path

During the course of this research the term critical path is frequently used. The critical path is the path of nodes through the decision tree that contains the minimum requirement to be able to conduct PBL contracts. A negative deviation from the critical path will result in a higher price or lower contracted availability. The critical path is determined upon the conducted interviews.

Because of the fact that the decision tree splits in the first node, the availability of planning information, there are two critical paths. One decision tree with planning information and a decision tree without planning information. It is desirable to have the planning information in advance, but lacking this information does not mean that PBL is not possible. Appendix E shows both options, where green represents the "desirable" critical path and red represents the critical path without the planning information.

Also visible in Appendix E are solid colored lines and dotted colored lines. The difference here is that the solid line depicts the bare minimum and the dotted lines represent deviations that may occur when this information is needed for a specific system under PBL. For clarification; the decision tree is built as a generic model so that it can be applied to several systems. It can be that one system is more complex than the other, which results in a requirement for more information. Thus a more complex the system will lead to more extensive information requirements.

To illustrate the critical path an explanation of the green critical path in Appendix E:

- Point A contains PBL information including the availability planning
- Point A.B is reached and for the critical path there is a need for information, hence the choice will be "restricted access".
- Point A.B.D represents the choice for "remote", "sharing", or "on site" availability of information. Because TNL will be responsible for the maintenance of the system, at least local access of the (system) information must be possible, hence the choice "on site".
- Point A.B.D.3 again has three choices. DPM data or dynamic preventive maintenance data is an important part of information for the sustainment of the system because it contains the current status of the system including hour counters, configuration information etc. This information does not contain the information regarding logging, behavior etc. This is the reason why the latter is dotted.

The critical path in the decision tree is a guideline. Whenever conducting the analysis, the path drawn in the tree will represent the information availability of that specific contract. When comparing this line with the critical path, the deviation will immediately be visible automatically suggesting that a change has to be made or not regarding the available information source(s).

Some of the nodes in the decision tree have identification. The identification correlates with a table in Appendix F. This table gives a brief explanation about the intention and consequences of the node. The consequences are represented by cost and availability and have a score:

- ++ Very positive effect on
- + Positive effect on
- +/- Neutral effect on
- - Negative effect on
- -- Very negative effect on

Thus if a node is a part of the path chosen during the information analysis its effect on the costs will be (see above) and its effect on the availability will be (see above). In preparation for an analysis of contractual information, the scores can be altered. At this time the scores are deducted from interviews and conversations with subject matter experts.

6.2 THE ANALYSIS PROCESS

Up till now the decision tree has been built and explained. To use the decision tree a simple set of steps have to be repeated (see Figure 13).

The first step is to start with a blank decision tree. Second the contract related documents are scanned for available information. Whenever a piece of information is identified, it has to be noted in the decision tree. Subsequently the search for information continues as well as the process until all identified information is noted in the decision tree.

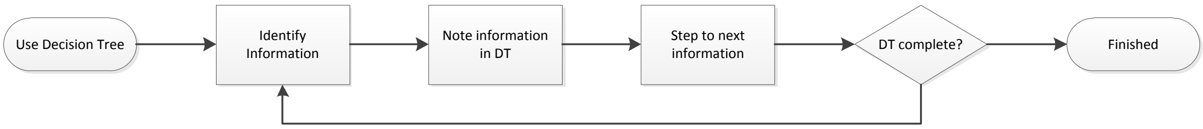

FIGURE 13 DECISION TREE PROCESS

The complete process of analysis is represented in Figure 14. The aim of this process is to give the user an overview of the possible follow up after completing the decision tree. The next paragraph will explain in more detail the function of the element in the process diagram.

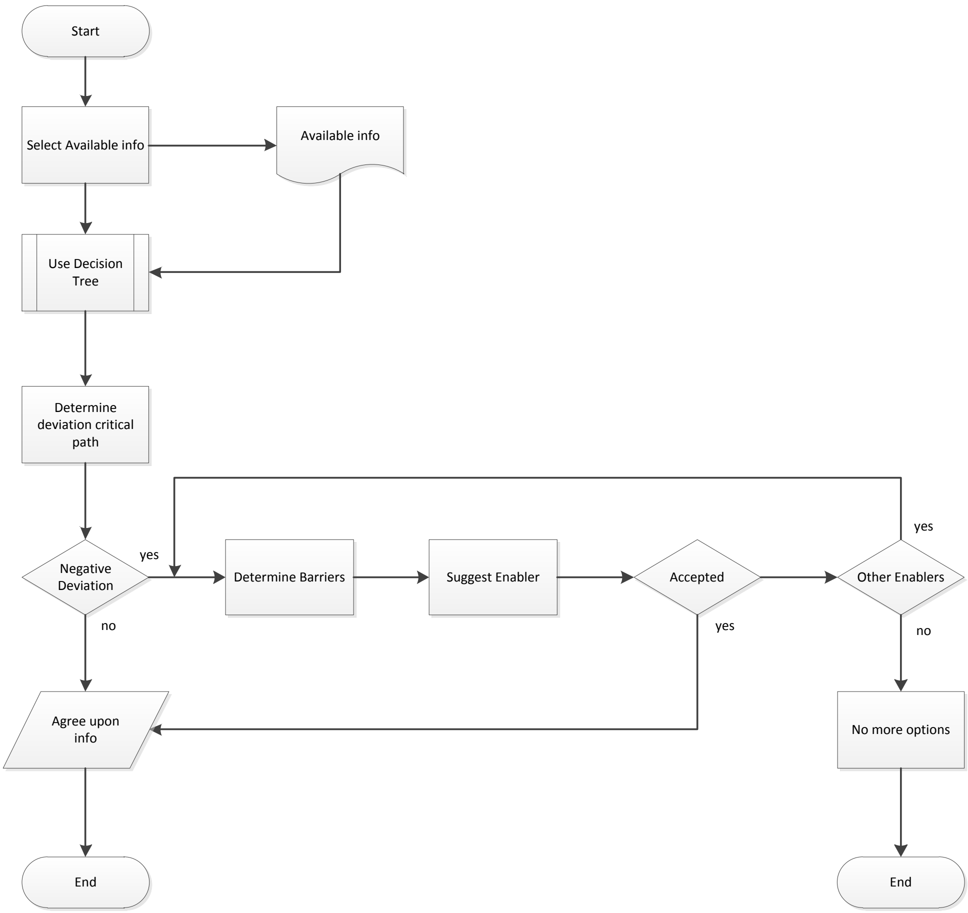

FIGURE 14 PROCESS DIAGRAM

6.2.1 Elaboration On process diagram

The elements of the process diagram (see Figure 14) are explained bulleted on element at a time:

1. *<u>Select available info</u>*
   The document or negotiations yield information that is available for PBL. Mostly this information is laid down in a (formal) document. It is key to highlight these elements.
2. *<u>Use Decision Tree</u>*
   When the information is identified and selected the decision tree can be used. The tree should be traversed step-by-step judging what information is available. The result should be a path through the tree. This process is represented in Figure 13.
3. *<u>Determine deviation critical path</u>*
   When the path is determined based upon the available information, it should be compared with the pre-determined critical path (see Decision Tree). If there is any deviation from the critical path this should be noted.
4. *<u>Negative Deviation</u>*
   If there is no negative deviation from the critical path (hence there is less information available then is needed), both parties (customer and PBL supplier) can agree upon the information at hand.
5. *<u>Determine Barriers</u>*
   If there is a negative deviation from the critical path, there is a need to identify the (possible) barriers that prevent the availability of the essential information. Hence why is the information not available.
6. *<u>Suggest Enabler</u>*
   It may be possible that there is an enabler that will result in the availability of the information, i.e. adjustment of the data quality, or falsifying of data (altering timestamps). If the suggested enabler is accepted, the process is finished. When the enabler is not accepted, this part of the process has to be repeated.
7. *<u>No more Options</u>*
   If there are no more enablers or the customers cannot be convinced to share the essential information for PBL implementation the process ends with a negative outcome. This negative outcome does not mean that a PBL contract is not possible. Offering a PBL contract is still an option but the costs of this contract will be so high that it is not very likely that the customer will sign this contract.

6.3 Encountered difficulties

During the research the information categories are defined. However when developing the decision tree it became clear that some parts of information do not fit into a specific category, but depending on the situation can shift from category. Thus in the choice of dimensions a more pragmatic approach is chosen and based upon the discussions the description of access to is a less strict in its definition, meaning that it covers the access to the information as well as the access to the system.

Up till now a lot of information is stored local. The experts know how to access this information and who keeps it up to date, but in order to have the information transparent for all process participants it is desirable to store the received information at a central location.

As described in chapter 5.3 there are two main barriers for the exchange of information cyber warfare and exchangeable information. Especially the first barrier forms a real threat for the flow of information regarding PBL activities.

Sharing planning information with regards to cyber warfare is not so much a problem, because this kind of information can be neutralized. However system information can be a problem because this implies the access of the system.

6.4 Enablers

Enablers are key for ensuring future availability of information. Summing up or identifying possible enablers would block future developments and innovations of enabling technologies. Hence the enablers mentioned in this thesis are limited and will be more extensive in due time.

An idea emerged during the discussion to be able to track spare parts and if this is a part of PBL. The tracking of spare parts is a part of PBL but it is out of scope for this research. Still it is worth mentioning; tracking of spare parts via RFID at the factory and on site locations. It is not new but it will improve the situational awareness of stocks. Hence availability of information will improve as well as the ability to trace the items.

6.4.1 Options for information exchange

During the research some options for information exchange are listed. This list is not complete and will deviate per customer of what is acceptable regarding security etc. One can think of the following principles and techniques:

1. Data Quality
    a. Data deterioration
    b. Deferred data
    c. Data selection
2. VPN
3. Repository
4. Email
5. Telephone
6. Asset at home base for maintenance.
7. ERP integration

To elaborate more on the topics in the list above:

- Data quality is explained in the previous chapters. Data deterioration can be done in different aspects. One is to neutralize the information, hence no relevant data, no identification of a system etc. Hence the information will be stripped of all context so that it is not possible to trace the entity where the information is about. Deterioration is applicable whenever information is exchanged between a system / DoD and TNL.
  Deferred data actually moves the data in such a way that it is still relevant for the technician but the operational value has diminished. A combination of deterioration and deferring of information is a good option.
  Last data selection; this is essentially a selection in time of an event log. This selection can contain the logging of the problem but it does not contain the complete history so for operational purposes it becomes less relevant.
- VPN established technology. Is an option for transferring of data both at home barrack as a remote location. The latter does imply that only smaller amounts of data can be exchanged due to the communication carrier.
  Remote connection to a system, if applicable, has to have at least the pre-condition that the initiation of the connection can only be done from the customer's side. This initiation can be a hardware switch or running a script, but the most important part is that there is no other option of connection. This will ensure that there will be no interference of a mission (un) intentionally

- Repository; this is something that is not very likely to be used to transfer system information between a DoD and TNL, but it can be used from a WFE's external location to communicate with TNL.
- Email; is a good option for sharing selections of the event log, defect reports and DPM data. As the information has a high impact regarding confidentiality, it is possible to send emails from a secure environment (confidential mail or a separate network).
- Telephone is a medium for sharing information, however this must be seen as a last resort. Due to the fact that the receiving end of the telephone conversation does not have visual access to the information, it is very easy to have a misunderstanding.
- Asset at home base for maintenance; regardless if the asset is a sensor on a ship, land based vehicle or an airplane, the WFE should have access to be able to extract information from the system. The access of the system can be done in a controlled environment (limited access, only for a selection of personnel with the appropriate clearance), preferably by means of a hot swap. This because a hot swap limits the access to the system and the event log can be stored completely on that medium.
- ERP integration; the majority of the larger companies use ERP systems as the main information system within the company. Also a lot of DoD's use ERP systems like SAP, therefore it is an option to apply middleware to exchange sustainment information. The middleware should be configured in such a way that only the reading rights are assigned to both parties so that only the systems under PBL can be viewed and mutual information cannot be altered on each other's systems but downloaded when needed.

6.5 Conclusion

The developed decision tree is kept generic so that it can be used for different systems. This implies that elements in the decision tree can change and the same goes for the critical path. However it is not intended to change the decision tree a whole for a system, only the elements will or can be specified to get more detail for that specific system.

Also there is more to PBL than only system information. The range of information extends even further than integrating the parts suppliers. It also includes tools, training of personnel keeping track of technical documentation. These last few topic are important when there has to be a logging of tools used in the context of certification (like in the aviation industry). However this research is limited to the exchange of information related to planning and the system under PBL.

The assumption is made that all data that will be received during the PBL contract will be stored at the same locations (databases) as it is done in the current situation. However some of these locations are local or interim. It is recommended to start clean upon the implementation of PBL products in the company catalog. This will prevent the loss of data quality, because the received information will be transparent company wide and thus all will use the latest version of the information received (see Figure 6).

7 Use Case

In this chapter the Use Case will be designed and described from the general situation to courses of action and the extremes. The purpose of this use case is to create an environment to be able to validate the information requirements analysis. This chapter is consists of the sections General, Scenario's, Analysis and Conclusion.

7.1 General

The basic setup of the use case is described here. By sketching the situation about a system that possibly will be contracted for Performance Based Logistics and the parties that are involved in conducting such a possible situation, the basic outline for the use case is set.

7.1.1 Situation

The OEM has developed a new sensor for use in land based operations, the Multi Mission Radar (MMR). The Multi Mission Radar (MMR) is a platform independent land based sensor. Due to its standardized (similar to 20 feet container) mounting it can be fitted to several means of transportation, i.e. wheeled or tracked, or on a static position placed on the ground or on containers to get ground clearance. The OEM intends to provide the option for PBL contracting to a potential customer. To be able to meet the level of availability agreed upon in the PBL contract, information is required. Thus the information that the customer is willing to provide related to the PBL contract must be analyzed whether if the offered information is sufficient to cover the information need of the OEM. Essential information elements are Data Quality and information availability.

7.1.2 Parties Involved

In the most abstract level a PBL contract there are only two parties, the DoD (nation depended) and the OEM. However this abstraction level is only representative for the contract negotiations and not for (a possible) implementation of a PBL contract. Thus to get a better overview, we have to go one step deeper to reveal the rest of stakeholders that are represented in the following roles:

1. Organizational Level Maintenance or OLM
2. DoD authority
3. Service Desk
4. PBL project team
5. Water Front Engineer or WFE

The relations are graphically represented in Figure 9. Although the system under PBL is not a naval system, the term Water Front Engineer (WFE) is still used. This is done because for the general population of TNL the title or term WFE is common and thus everybody has an understanding of what a WFE does and can do. In due time WFE probably will be replaced with another title, but during this research WFE will be used.

The role of OLM (probably) will remain at the same person(s) or level, due to the fact that the OLM is the entity that conducts maintenance and/or repairs on site. Actions performed by an OLM will be most of the time during a deployment or a Field Training Exercise (FTX).

The role of DoD authority on the other hand is a role that has the potential to switch from a department or position (post) to another department or position (post) in the DoD organization. To be more specific, during negotiations the DoD authority is actually a part of the organization that conducts the market surveys and does the contract negotiations. But whenever the PBL contract is in place, the role of DoD authority moves down the organization to a lower level. This means that the communication will be done via one person or one office consisting of a limited set of personnel. Thus the role or "responsibility" can and will shift through the organization.

The role service desk is not really a role but an existing section within Thales Nederland Customer Services and Support and an important stakeholder within the execution of PBL contracts. The activities of the service desk will not change, but it is still the single point of contact (or front office) for the customer when there is an issue.

The PBL project team is, as the name implies, is a team of multiple players that can vary in size and will be tailor made for a specific PBL contract. Because of its changing nature it is defined as a role. There will be no further elaboration on the composition of the PBL project team, except the fact that there will be a PBL project manager. The PBL project manager will have the lead in the PBL project team and will be responsible for the overall coordination and execution of the standing PBL contract.

The Water Front Engineer is an engineer that is on site and has the knowledge, ability and equipment to conduct maintenance and diagnose and repair the most issues that can occur on a TNL system.

7.2 Scenario's

7.2.1 General

A DoD is interested in the Multi Mission Radar including PBL contracting. During the negotiations it becomes clear that there are three different situations of use; Home Base, Field Training Exercise and Deployment. Only with the first situation the physical location of the MMR is known beforehand. Regarding the other two situations, the locations of the MMR will be known but there is a considerable shorter lead time especially on the Deployment.

In the following sub-sections each situation will be described including possible restrictions or implications on information exchange.

An assumption is made that the MMR is always a responsibility of a unit, regardless if this is a maintenance unit or any other operational unit. For this Use Case the sensor is assigned to an operational unit that is equipped with an OLM.

A Material Availability Plan (MAP) is a plan that contains the planning of the systems when they have to be available for the customer.

The options of use can be limited to three, but within these options there are several variables that can differ. Fully aware of the fact that there are more options or deviations possible per situation a fixed set of variables is selected in order to narrow the scope. The chosen options per situation will be the most likely, hence it always can deviate but there is a high probability that this is the way that the customer will operate.

7.2.2 Home Base (HB)

In normal day-to-day operations the sensor or MMR is at the barracks where the assigned unit is stationed. The WFE is on-site and has access to the sensors. The OLM personnel are on the same barracks and can work as a team with the WFE. Due to the access to the system the download of the Event Log (EL) is possible and the WFE has communication means with TNL. Software updates of the sensor(s) can be executed but in a secure environment due to awareness of cyber warfare. In this case remote monitoring is not needed due to the presence of a WFE and the possibility of sharing of information can be done via mail or communication by phone. The MAP is available for TNL (hence the Service Desk, PBL Project Team and WFE). Figure 15 is a Data Flow Diagram (DFD) that depicts the information flow in this scenario.

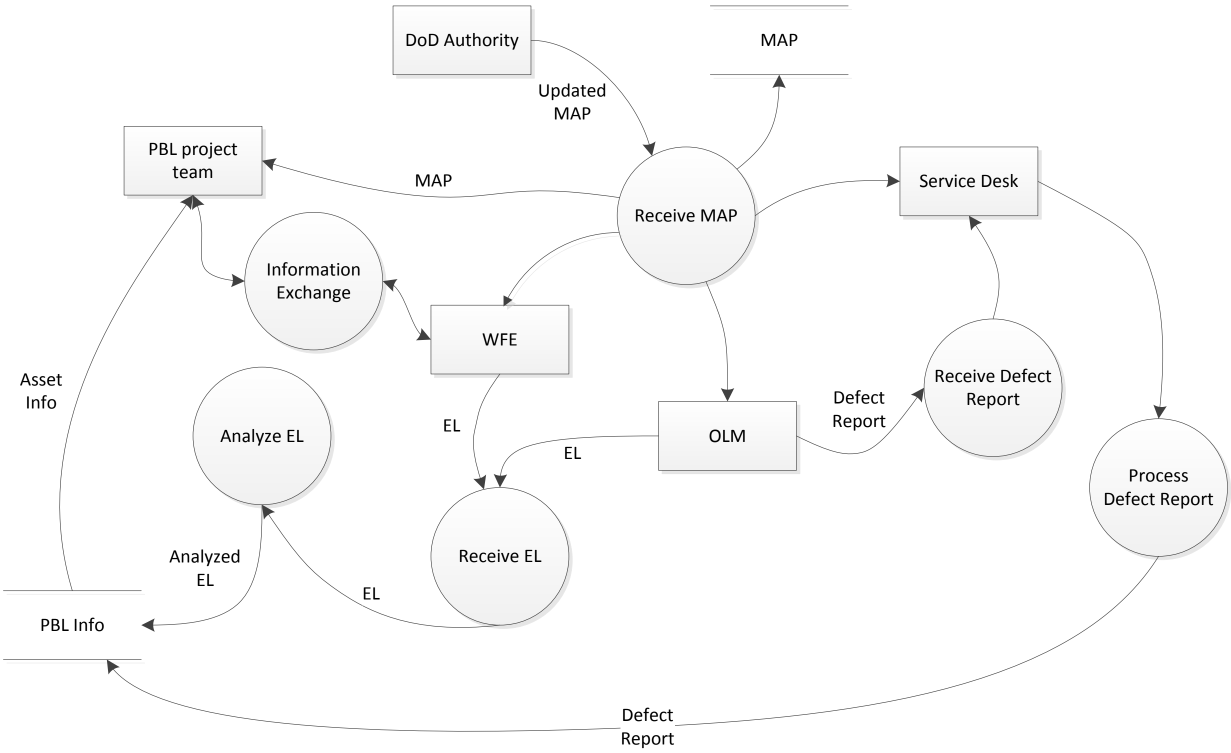

FIGURE 15 HOME BASE SCENARIO

7.2.3 FIELD TRAINING EXERCISE (FTX)

A Field Training Exercise or FTX is an event that is used to train military personnel in skills and drills including using their equipment, hence a simulation of war conditions.

An FTX can be planned and is added to and visible the on MAP. Due to the fact that there is plenty of lead-time to prepare for the FTX, pre deployment checks are possible. During the FTX is not on site but the OLM has the means to communicate with the WFE. In the communication the sharing of defect reports is possible. Only on exceptional cases there is a possibility to share a selection of the Event Log.

Remote monitoring is not an option due to the limited time span of the FTX and the cost of the communication channel. The time span that systems are not available for the WFE is 6 weeks on average including the transportation of the systems.

Figure 16 is a Data Flow Diagram (DFD) that depicts the information flow in this scenario.

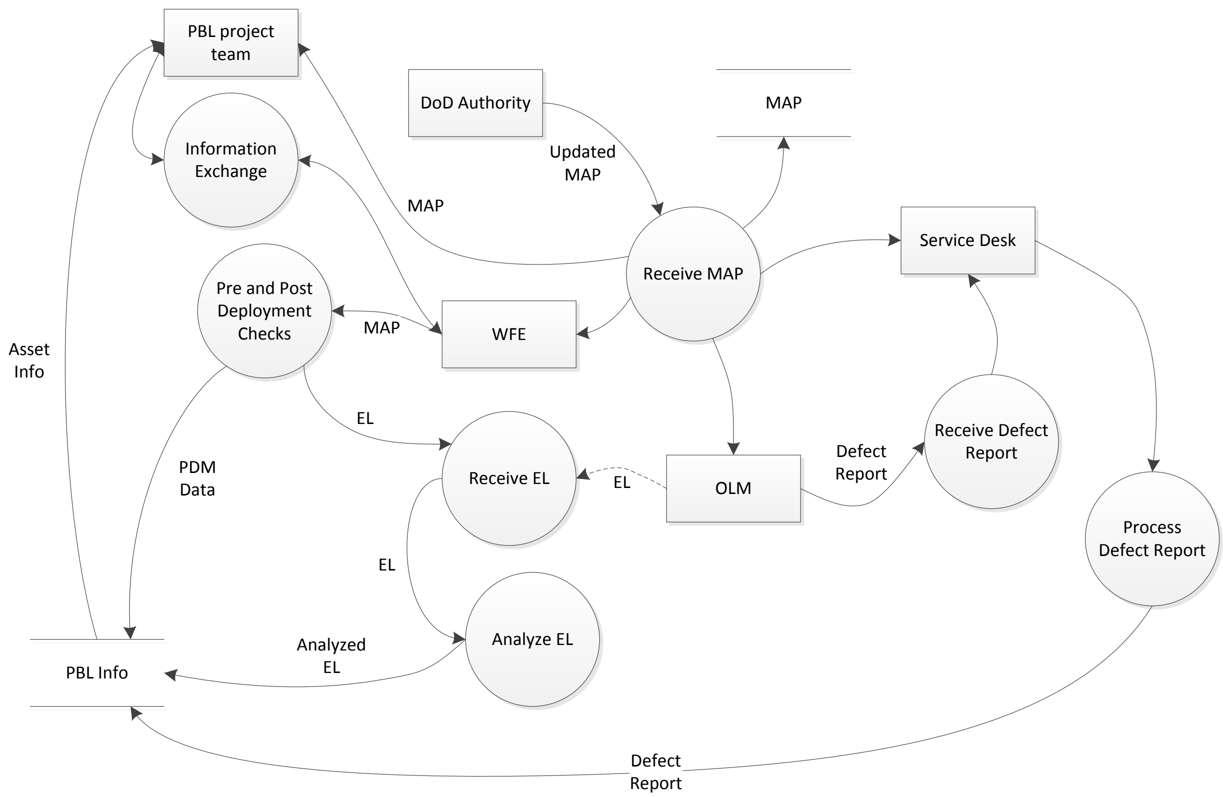

FIGURE 16 FTX SCENARIO

Post deployment checks are possible (by the WFE together with the OLM) including a download of selection of the Event Log (timespan of the FTX). The WFE again has communication means on hand to send the EL to TNL.

7.2.4 Deployment

Sometimes a deployment can be planned well in advance, however it is not uncommon to have a very short lead time to deploy a piece of equipment (in general) as a result these deployments are not included in the MAP.

In this case there is a short lead-time to deployment (approximately 8 to 12 weeks) and therefore it is not included in the initial MAP. During this short lead-time the personnel has to practice drills for the last time, and the equipment has to be packed and prepared for transport. So somewhere in this time frame pre deployment checks and maintenance on the systems have to be conducted. As in many land based deployments, it is not clear when or if the system returns.

During the deployment there is no WFE on site and the OLM personnel will change every 4 to 6 months.

Due to the remote location and the nature of the deployment and its ongoing operations, there is a limited possibility for exchange of information. Probably there will be a possibility to send a selection of the Event Log via secure mail. Telephone conversations are limited and probably will be done via a secure connection due to the importance of a system (sensor). However defect reports can be made available via the DoD authority. Due to all restrictions a remote connection or Telemaintenance on the system under PBL is not possible.

The system (sensor) is important for protection of the bases occupied in the operation area. In the protection of the bases the main objective is the safety of the personnel present on the bases. As a result the DoD wants periodically updates on how the systems will be kept operational and advice on spare parts and maintenance capacity in the operation area.

Figure 17 is a Data Flow Diagram (DFD) that depicts the information flow in this scenario.

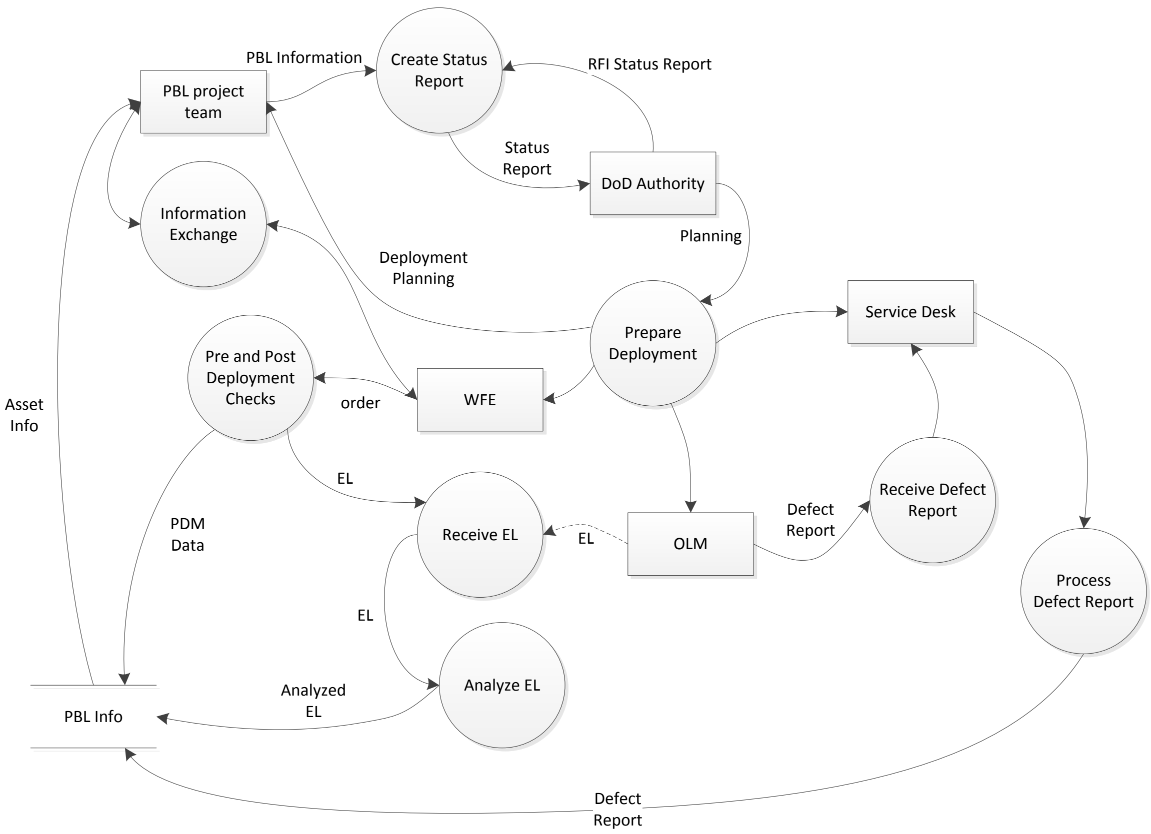

FIGURE 17 DEPLOYMENT SCENARIO

7.3 Analysis

The Use Case scenarios described in the previous sections need to be analyzed using the Decision Tree. This chapter provides guidance how to use the decision tree and explains the process schema. The actual analysis process is described in chapter 6. In order to prevent repetition the Analysis Process will not be described in this chapter. However when conducting the use case, the analysis process will be present in the complete description of the use case.

7.3.1 Analysis Process

Chapter 6.2 covers the analysis process. The description given and elaboration on the process diagram will be in the use case once it is executed. Figure 14 graphically represents the process schema and is intended to function as a user's guideline. Chapter 8 elaborates on the validation of the decision tree. During the validation the use case is executed by conducting the analysis. The result will be a decision tree with a situation specific path indicating the different options and choices made.

7.3.2 End Result

Once the process has been executed, there is an end result that reflects the current situation of the (potential) available information and its position in relation to the critical path in the decision tree. It is up to the PBL supplier if a PBL contract is signed or not, even if there is a risk of not having the proper information. Still the decision tree will give an overview in which node improvement has to be made in order to obtain the information to support the PBL process for the PBL supplier.

8 VALIDATION

Every developed solution requires a validation in order to proof that the solution is feasible in the intended environment. The aim of the validation session is to prove that the developed decision tree is useable for the information availability analysis process conducted when engaging a possible PBL contract. Hence does the developed solution answer the main research question; "*Can a solution be developed for analyzing contractual information requirements in order to be able to facilitate information system data exchange*?" The validation is conducted in a session with Subject Matter Experts (SME's) with the use of a use case. The main topic of the use case is a land-based sensor, which will be exposed to three different circumstances (scenario's) that are realistic but not detailed to the extreme.

During the validation all comments, emerging effects and outcomes will be noted. At the end of the session an overall conclusion is drawn about the feasibility of the decision tree. This chapter describes subsequently the setup of the validation session, the participants, the execution of the validation, the results and the conclusions.

8.1 THE SETUP

For the validation the use case from chapter 7 is used. It describes the use case that has a land-based sensor as a system for a potential PBL contract. To stress the varying circumstances three different scenarios are available to cover these situations. The focus of the session is to validate the decision tree as an analysis model for PBL information. To keep the focus on the system and planning information the use case is limited and topics like i.e. re-design are not involved in the use case nor validation.

Going a bit of topic but still worth mentioning; re-design is something that can be a result of the analysis of received PBL information. Thus whenever a contract is signed, in due time a certain amount of information will be collected and or deducted. Analyzing this information gives an insight in the system and it's supporting processes. If too much anomalies and or malfunctions are found, a re-design can be the only solution. This is why the PBL project team is a generic role of which the composition can change per project or system under PBL. It is possible that a system engineer is a member of this team that initiates a redesign of a certain part or software.

Again the basis of the validation is a use case with three scenario's to incorporate the dynamics of land-based operations. The participants receive three decision trees each, one for every scenario.

It is the intention to let the participants do some exercises, creating a path through the decision tree based on the use case. In total there will be three iterations, where in each step the scenario will be more complex but realistic. The idea is to let every participant build a path in the decision tree based upon the scenario. When finished one participant presents its decision tree resulting in a discussion with the remaining participants, where they give feedback on their experience of usability of the decision tree.

The time slot available for the validation is 2 hours, which is a short timespan but due to availability of the participants the only option. To utilize al available time, a strict planning is made (Table 3).

Time (minutes)	Subject
10	Intro (10 min)
20	Explanation Use Case (10 min)
30	Use Case, Scenario 1 (30 min)
40	
50	
60	Use Case, Scenario 2 (30 min)
70	
80	
90	Use Case, Scenario 3 (30 min)
100	
110	
120	Wrap-up (10 min)

TABLE 3 TIME TABLE

The introduction covers the outline of the validation and a short explanation of the stakeholders/roles within the boundaries of the PBL contract (Figure 9). The participants might know the decision tree, but the complete research is not familiar. Therefore a short refresh is done to get all the participants up to speed regarding to terminology and abbreviations.

The use case is explained in a nutshell, including the pre-conditions. Each participant receives a set that contains the use case (chapter 7) and 3 blank decision trees. To ensure that the participants have a common understanding of the scenario, every sub session is also started with a brief explanation. Every scenario must be executed in the same sequence, therefore the following steps are repeated with every scenario:

1. Short explanation of scenario and DFD by the moderator. Every participant has complete use case including the DFD in hardcopy as a reference.
2. Start the decision tree by participants
    a. Determine the information availability at each step
    b. Write down findings
    c. Repeat until end of the decision tree
3. Presentation of result by one participant
4. Discussion
5. Conclusion

8.2 The Participants

During the research a selected set of subject matter experts are interviewed. Nearly the same set of SME's are the participants for the validation session. The participants:

1. Service Portfolio Manager
2. Logistic Engineer
3. System Engineer
4. Manager Bid Support

All the participants are experts in their area and are involved in the development of PBL contracting and execution of a small PBL contract within TNL. In the process of developing a product or a service like Performance Based Logistics the personnel in the different departments have developed by conducting research and training regarding PBL aspects. Also the development of the PBL product has been done with engaging peer experts in the respective areas. Therefore the participants are able to deliver well-funded comments during the validation.

8.3 Conducting the Validation

The available time is limited, due to the fact that it is very difficult to get all players in the same session. Unfortunately other options were not possible. Per scenario each participant made a decision tree, including comments of items that are not correct or are missing.

8.3.1 Scenario 1

Scenario 1 is a simple home base scenario. The unit that is the user of the sensor is at its home base, the barracks. The OLM is onsite as well as the WFE, so there is a face-to-face exchange of (mostly informal) information. The WFE has access to the sensor in a secure environment and also has access to the MAP. Thus most relevant information available, however not all options of communication are as one would like. For more details on scenario 1 see paragraph 7.2.2.

8.3.1.1 Outcome

Every participant made its own decision tree using the available information from the scenario and was able to use the decision tree to distil the information from the text and project it onto the decision tree. While creating a path through the decision tree, the participants concluded that there is sufficient information for conducting a PBL contract. This lead to a drawn path from “Availability planning” via “Restricted access” to “ Onsite Event log”

This is the expected outcome due to the fact that basic scenario is obviously not that complex to analyze. Three of the four participants have nearly the same result (small differences). Especially the fact that the decision tree gives a direct insight into the available information is mentioned as positive as well as confronting because the information (and the possible lack of) becomes graphically visible.

8.3.1.2 Differences

The System Engineer had a different outcome. He approached the scenario and the decision tree from the standpoint of what kind of information he wanted and how, hence focus on remote access of the system. This scenario does not offer the option of remote access and thus resulting in a lot of questions on how the information would be available to the system engineers. But despite his result, he acknowledged the steps made by the other participants. The fact that questions are raised about the information should be made available to the system engineers has an emerging effect; being confronted with information deprivation, one focuses on what is essential to work instead of gathering information that a sensor is able to produce. This does not mean that this information is not important; it simply will arrive on a time-shifted moment.

The fact that the outcome of the majority of the participant is the same as the expected (and desired) outcome, the decision tree is useable for the first scenario.

An adjustment to the DFDs (also from the other scenarios) has been made due to the remark of a participant that the DFD had a flaw. There was no information exchange process defined between the WFE and the PBL project team, hence the change of the DFDs.

8.3.2 Scenario 2

Scenario 2 is a scenario about a field training exercise (FTX). Again this scenario is not to complex but still limitations are present due to geographical dislocation. The unit is conducting an exercise with the sensor(s) and therefore is not on the barracks. This training deployment puts limitations on the availability of communications. Because of the geographical dislocation, the WFE will not be onsite, however communication between the OLM and the WFE is possible. The FTX is visible on the MAP, which is also available to the OEM (and thus the WFE). The timespan of the FTX including transport is 6 weeks. As usual pre and post deployment checks are possible. For more details on the scenario see paragraph 7.2.3.

8.3.2.1 Outcome

In this scenario it was possible for all participants to conduct the analysis by means of the decision tree. Overall the second scenario seemed to be easier on the participant, while it is more complex. This emerging of learning effect makes that the participants better understand the principle of the decision tree and therefore are able to utilize the decision tree better. By applying the decision tree more often, the process of analysis will become more fluid.

Another emerging effect is that the decision tree is used to depict all options. Although it is not intended this approach covers a what-if scenario and give a graphical representation and therefore more insight in the available information. For example in the current scenario three from the four participants also selected the branch no system access because of the physical dislocation, however the information was available via pre and post deployment checks. The latter is recorded in the decision tree as well.

The filled out decision tree forced a different view of the situation, this arose more questions with the participants. Again this was not the aim of the scenario, but it stresses the fact that this analysis gives more insight to the availability of the information. Each participant being an expert on his area sees potential short falls in his process when he lacks information.

The emerging effects are caused by the graphical representation of the available information and the confrontation of possible lack of information.

The participants see the decision tree useful in this scenario because besides the advantages in scenario 1 it can hold all information options and not only one single track. This means that the effects of two different approaches of information availability can be compared also regarding the effects that a choice in the decision tree will have on the execution of a PBL contract.

8.3.2.2 Differences

In this scenario there are little differences between the participants. The only difference is that the system engineer did not draw the path to “no system access”. The other participants did, but only because the decision tree is used to depict all options of information exchange.

8.3.3 Scenario 3

Scenario 3 is a scenario about a deployment with an uncertainty if the system returns. This scenario is the most complex scenario to retrieve information. It is deliberately made complex in order to make it difficult to access the information regardless of the decision tree.

The sensor will be deployed with a short lead-time. As a result this deployment is not on the MAP. There is time for the personnel to train the drills and there is time for the WFE together with the OLM to do the pre-deployment checks. Due to the nature of the deployment and operational security there is a limited possibility to exchange information. The sensor will remain in the operation area and the return is not known. An additional complexity; the OLM personnel will change every 4 to 6 months. See paragraph 7.2.4 for more details on the scenario.

8.3.3.1 Outcome

The expected outcome is that the PBL contract is feasible but probably some concessions have to be made. The participants will create probably more than one path through the decision tree.

The participants projected the information in the scenario on the decision tree with more ease. Also the participants mention that during the process of analyzing the information it becomes easier to use the decision tree. As a result there is more focus on the information itself and the effects it will have if it is present or not.

In this scenario the decision tree is found useful by the participants because of the focus on the information and the possible accessibility of a sensor to retrieve information.

Every participant found the same path through the decision tree. However there are differences between the created decision trees, mostly as a consequence from the noting all available information options in the tree.

8.3.3.2 DIFFERENCES

What stood out is that there are differences regarding the path in the decision tree between the participants. The differences are not shocking, but they point out the different areas of expertise of the participants. This means that the engineer looks at data to improve the system and the logistic expert looks at behavioral data to determine stocks and maintenance intervals.

Despite the differences in the decision tree, discussion of the results will lead to a better overall view of the situation regarding information availability.

The differences in the decision tree paths also stress the need to conduct the analysis in broader setting, simply because of the fact that when a scenario or a situation becomes more complex every SME contributes in his specific area. The expert on bid support stresses that the decision tree creates awareness of barriers in the information flow and the importance of the availability of information throughout the execution of the PBL contract. Therefore he recommends that such an analysis should be conducted together with the customer to create the same awareness on the information need.

The obtained insight from an analysis of a complex situation should be recorded in the contract.

8.4 RESULTS

There is no extensive experience within TNL regarding PBL contracting. The product/service is relatively new for TNL. PBL is actually a contract for availability and thus the customer pays for a working system. Of course there is an extensive experience on all logistic areas within TNL, but PBL is a different approach. All expertise is there, it has to be utilized in a different manner. And this organization is exactly what leads to the information requirement to be able to execute PBL. All SME's have done research and training within their area of expertise regarding to PBL and this together with their experience makes them highly capable to participate in a validation session.

In every scenario different choices in the decision tree are possible, all depending on interpretation of the scenario. The subject matter experts had slight differences in the decision tree, but in the end they had the same focus or end idea of what was possible and what needed to happen to be able to support PBL for a product. This event was also visible when comparing the decision tree to of the participants to the expected outcome. The main line that was created was close to the possible solution (that was the most obvious) and had only slight deviations, merely caused by the interpretation differences of the participants. The decision tree is intended to function as an analysis model that can be filled out to the perspective of its user. When using the decision tree in a broader setting everyone has its vision or idea on a certain topic that will lead to a collective point of view. Because of the difference in interpretation deviations are possible in the chosen path through the decision tree.

The schema of the decision tree was not completely new to the participants. But the idea was to get an objective reaction from the participants, therefore they had no preparation prior to the session. Normally the critical path (in the decision tree) is set in preparation to the analysis of an upcoming PBL contract to be able to determine the deviation and search for enablers to mitigate gaps in the actual and desired situation. But as stated this was not the case during the validation session, this resulted in more focus on the decision tree itself.

After the start of the analysis and some discussion the participants were able to use the decision tree. The use of the decision tree gives participants more situational awareness about information availability. Eventually the greater situational awareness will point out the lack of information experienced by the participants, information that was assumed to be available. The emerging effect here is the awareness of the fact that not always information is available or accessible. Hence TNL personnel have to work with the information they have, resulting in the importance of the data quality of the data stored in the standing system.

There are intentionally three scenario's made for one use case not to be creative but to point out that a system can and will be used under different circumstances.

Due to the fact that there is little deviation in the created decision trees by the participants, indicates that there the method is easily applicable and therefore very useful for everyone that is new to PBL.

8.5 Conclusion

The use of the decision tree has a learning effect. The first time the participants need to look at the decision tree to be able to make the right choices. Every following repetition is easier. The end conclusion is that the decision tree is a useable analysis model that will not only give an insight on the information availability, but also reflects on the impact for the sustainment process.

An emerging effect of the use of the decision tree (and the validation) is that, regardless of the scenario, the participants are confronted with possibilities of what could happen in real-life. As a result a lot of what ifs emerge, most of them probably have to be captured in contracts in order to have no misunderstandings between customer and TNL (PBL supplier). Besides the what if's, the confrontation with the fact that the available information will change per customer (thus per nation) will make it even more complex for the participants. They come to realize that there is a lot more to PBL than meets the eye, a lot of business processes need to be adjusted, recalculation of stocks (spares) and stock-locations need to be done etc. But all the amendments that need to be in place before the offering of a contract for availability results in a flow of information. This flow of information will start at the first delivery of a system and has to be transparent for all of TNL. The latter is also important due to the fact that it is possible that no information is available during deployment. If this is the case the TNL personnel has to depend on the latest standing information and therefore this has to reflect the reality as close as possible.

The developed method is useable for both people new to PBL as well as experienced personnel. The first group will be able to analyze information availability step by step, where the second group can use the decision tree not only in support of their analysis but also to create the awareness at the customer to see the necessity of information availability.

9 CONCLUSIONS AND FURTHER WORK

PBL related information is more than only logistic information, it is also about understanding the restrictions on information exchange at the customer side. These restrictions can have several causes. It is important not to see the barriers as problems, but to find opportunities to share information. If it is not possible to physically connect to a system, than enable the customer to push the information. If this means that there has to be an interface to a PBL database, so be it. Hence do not emphasize barriers, provide enablers to share information.

9.1 CONCLUSIONS

During the validation it is determined that the decision tree coined for analysis of contractual information requirements works as expected. It gives an insight in the availability of information related to a (potential) Performance Based Logistics contract. It also clarifies the threats for conducting PBL (contract) due to the lack of required information. Although the analysis does not give a solution for information availability issues, it highlights which areas in the information will be an issue.

PBL contract related information is not limited to an information flow from the customer to the PBL supplier (TNL). Even if there is a contract for availability, the customer wants to be informed about the operational status and operational risks of the system under PBL. The operational status is relatively easy, the system is functional or not. The operational risks on the other hand is something different, the PBL provider needs to take into account that reports are required prior to the deployment of a system. Hence is the system capable to be used during the mission without severe issues? Thus the information flow is bi-directional instead of merely a flow from customer to PBL provider. At the start of the research the focus was on the information requirement for conducting Performance Based Logistics, based on the flow of information from DoD to OEM. Over time it became clear that besides the information flow for conducting Performance Based Logistics there is a reporting flow, ad hoc and periodically from OEM to DoD.

When an analysis has to be conducted on a potential PBL contract, it is essential to conduct this analysis with several experts from the OEM and DoD. Every expert has his ideas about what information is needed and although a consensus situation often is the case during an analysis, the different viewpoints make a complete picture and prevent the loss of essential details. The results of the analysis conducted by DoD and OEM can be used by the OEM to setup the organization and (IS) technology needed for the contract as well as determining the price of the PBL contract.

Exchange of information is always sensitive in the world of Defense, but Cyber Warfare is a serious challenge. The drastic measures that often are taken to prevent any form of malicious code on a system often turns out to be a complete shielding. Hence no connections are possible. Mitigating potential barriers heavily depend on the safety policy of the customer. On site data access seems to be the most feasible option, but still access to the systems have to be granted. When the customer is not willing to negotiate easing of the safety policy, one has to wonder if this is a good starting point for a PBL contract.

With the start of a PBL contract, the flow of information will start as well. All received information should be stored in the standing systems. However some of the stores are ad hoc or local. The information gained from the PBL contract will be used throughout the company, therefore it is essential that the information is initially available for every participant in the PBL process.

Although there are probably not a lot of customers (DoD's) willing to grant real-time access to a system during deployment (regarding cyber warfare), system engineers still see it as an option to monitor when a system does not function as it should. Remote troubleshooting potentially reduces costs and duration of repairs.

9.2 RECOMMENDATIONS / FURTHER WORK

With this research the information analysis for Performance Based Logistics is covered. The results of the (joint) analysis will form the first step of the initial phase of PBL contracting. With the input of the analysis the initial phase of a PBL contract the OEM needs to arrange its organizational settings including a supporting Information System in the form of a MMIS like tooling package, to be able to conduct the PBL process.

Thales specific; A lot of databases and business (legacy) systems are in place and there is an ongoing transition from the "legacy" systems to new up to date business information systems for the support of the different business processes. A point that stood out during the conducted interviews; is that there is already a lot of information present in the organization but the availability and storage (and administration) is mostly ad hoc. Because the information generated from PBL contracts is needed throughout TNL, it is essential to start clean. Information transparency is key when more than one department, business unit, etc. utilize this information for their internal processes. Thus when implementing PBL and a MMIS, it is recommended to integrate such a system not based upon databases of legacy systems, but to setup a new database to store all incoming information regarding PBL.

A Maintenance Management Information System (MMIS) is common to be implemented prior to the operational phase of a PBL project. Such a MMIS is needed to organize the information related to and generated by the PBL project. Because of the fact that a lot of customers of TNL use ERP systems, it is desirable to be able to read and process ERP information in the MMIS.

To keep evolving the customers support and to ensure the flow of information, it can be an option to develop (or buy COTS) middleware to enable ERP integration. This middleware can enable the option to read a selection of information from the customers ERP system and vice versa. Offering such an option of system integration can relief the customer from potential workload regarding the information flow. When implemented it can also ensure timeliness in the information flow to the OEM.

TNL specific; In the beginning of this thesis an observation is made about the involvement of suppliers of TNL in the PBL process. When there is a supplier that repairs parts, TNL would like to know the location or the progress, hence tracking and tracing. This implies another party for information exchange. A third (or more) party is considered out of scope for this thesis, but it is a part of the complete PBL chain. A solution might be the use of RFID chips on all spare parts in stock at TNL. Tracking and tracing will improve the situational awareness of stock throughout the company. Therefore it is recommended to investigate feasibility of the implementation of RFID in the spare parts process in relation to the further development of PBL operations. An extension option is; tracking and tracing spare parts at the location of third parties.

When the first PBL contract is in place, it is recommended to research the possibility and feasibility for a Performance Based Logistics information system integration for the complete chain. Ultimately utilizing the information through the complete process from DoD to OEM to subcontractor of supplier.

Registration of tools, training of personnel and documentation may be worthwhile to incorporate into PBL information requirements in the future, because of certification (like in the aviation industry). During this research this was discarded, but it may be a topic for further research.

Abbreviations

CALS	Continuous Acquisition Lifecycle Support
CMMS	Computerized Maintenance Management (Information) System
DLM	Depot Level Maintenance
DoD	Department of Defense
DPM	Dynamic Preventive Maintenance
DQ	Data Quality
EDI	Electronic Data Interchange
EDIFACT	Electronic Data Interchange For Administration, Commerce and Transport
ELOT	End Life Of Type (the technical and/or economical end date of the system)
FFP	Firm Fixed Price
FRACAS	Failure Reporting, Analysis and Corrective Action System
FTX	Field Training Exercise
ILM	Intermediate Level Maintenance
JSON	JavaScript Object Notation
LSA	Logistic Support Analysis
LSAR	Logistic Support Analysis Record
MC	Maintenance Center
NCDM	NATO CALS Data Model
OLM	Organizational Level Maintenance
PBL	Performance Based Logistics
PLM	Product Lifecycle Management
PSP	Product Support Process
RFID	Radio Frequency Identification
SLA	Service Level Agreement
XML	Extensible Markup Language

LIST OF FIGURES

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APPENDIX A

Information Requirements (Interview Results)

Group			Element	Category	Class	Deferring Time	From	To	System / DB	Contact	Remarks
	?		Internal and External Case nr	System Status	Real time	on demand	Service Desk	Service Desk	?	RY	de fracas case nr, als het overgaat in een andere db, de geassocieerde case nr. Dit is intern Thales en niet de informatie uitwisseling met een DoD
Logging	A	1	Error files	System Status	Deferred	on demand	DoD Authority	Service Desk	FRACAS/JIRA	RY / GR	Once every 6 months or sooner when needed. JIRA details are important see also identification and equipment. Detail: at the level of the item that has to be exchanged on the system
Logging	A	2	Event logs	System Status	Deferred	on demand	Other	Service Desk	Local Ad Hoc	RadS / RY/ EW	Diagnostics log. Needed on demand whenever there is an event. Engineers need information to resolve events. In the event logs all het to be time stamped. Also logging of startup sequence. However, when maintenance is executed the complete event logs are down-loaded for future system development (&improvement). These event logs can thus be transferred by OLM, DoD authority or the WFE to the service desk (all depending on the level of maintenance).
Logging	A	3	Defect Report (aka Intervention Form)	System Status	Deferred	on demand	Other	Service Desk	Local Ad Hoc	RadS / FS	Defect report on demand whenever an event occurs. If asset fails the report is generated and send to the SD
Logging	A	4	LRU Information	System Status	Deferred	on demand	DoD Authority	Service Desk	Local Ad Hoc	RadS	All LRU information: LRU Failure report Fault History Hour Counter On/off Switch Counter Temperature log Normally during scheduled maintenance or via defect report Detailed information registration on LRU level
Logging	A	5	Operational Data Logging	System Status	Deferred	on demand	Other	Service Desk	Local Ad Hoc	RadS	On demand: whenever an asset is available for access or maintenance, the data will be downloaded. However this is Operational Deployment Data
Ops Hrs	B	1	Life / Operating hrs	System Status	Deferred	6 months	DoD Authority	Service Desk	Excel sheet / JIRA	RY / GR / EW	The actual life of a wear out item. (per sn if it is a wear out item). The coun-ters per item. Information can also be provided during maintenance. So WFE or OLM. Note: some counters are not automated.
Condition Based Monitoring	C	1	Condition based monitoring data	System Status	Deferred	none	DoD Authority	PBL Project Team	Local Ad Hoc / Excel / JIRA	RY/ EW / RadS / GR	At the level of the item that has to be exchanged on the system, it has to be semi-real-time. This includes all sensor data, environmentals etc. -Temperature -Airflow and liquid flow -Motor current -Dust filters This information has to be able to be monitored Real-time and Deferred (logging) 6 month interval
Condition Based Monitoring	C	2	Temperature	System Status	Deferred	6 months	OLM	Service Desk	Excel / JIRA	EW/ GR	Data from several temp sensors, internal and external. Data will be logged and read when needed, minimal once per 6 months
Condition Based Monitoring	C	3	Environmentals	System Status	Deferred	1 week	OLM	Service Desk	?	EW	Buildup historic data irt behavior, weather station required. Frequency 1 x week
Config	D	2	Items to be tracked by sn	System Status	Deferred	pre and post deployment	Other	Service Desk	COMA	RY	some items need to be traced and tracked by sn
Config	D	1	Configuration Information	System Status	Deferred	on demand	Other	Service Desk	Relex / COMA / JIRA	RadS/ RY/ GR	The systems basic information. This info is needed once every 3-6 months or whenever a ship / asset is scheduled for maintenance. Pre- and Post-deployment - Revision of a sn - SW version - Location - Ship

	D	3a	Identification	System Status	Deferred	on demand	DoD Authority	Service Desk	Excel / JIRA	GR	1st level of breakdown of System
	D	3b	Equipment	System Status	Deferred	on demand	DoD Authority	Service Desk	Excel / JIRA	GR	What kind of equipment is it? System identification (highest level)
Status Info	E	1	Status	System Status	Deferred	pre and post deployment	Service Desk	Service Desk	Local Ad Hoc	RY	status of MSI, functioning etc.
	E	2	Operational System Status	System Control	Real time	none	Other	Other	?	EW	Upon malfunction, system information. Can be via WFE on site or OLM and thus via remote connection.
	E	3	Health Report	System Status	Deferred	on demand	Other	Service Desk	Local Ad Hoc / Excel / JIRA	RadS/ GR	Generated Health reports, timings not clear but needed to predict perfor-mance on non LRU's. Interval every 3-6 month no matter if asset is available for WFE or not. This implies data transfer during deployment / training.
	F	1	Non automated data	System Status	Deferred	pre and post deployment	WFE	Service Desk	ORACLE / COMA / FRACAS/JIRA	RY	Counters and other asset related data (i.e. spares) that are not automated thus has to be noted by the WFE and send to the Service Desk
Maintenance	G	1	Maintenance planning	System Planning	Deferred	6 months	DoD Authority	Service Desk	Local Ad Hoc	EW/ RadS	Operational deployment planning / availability planning for general preven-tive maintenance. Frequency 6 months or upon change.
	G	2	Maintenance Report	System Status	Deferred	on demand	Other	Service Desk	Local Ad Hoc	RadS	Generated Maintenance reports of conducted "preventive" maintenance. Can be done when asset scheduled for maintenance
	G	3	Issue Registration Repair/Spare/Technical Issue /Other	System Planning	Deferred	on demand	DoD Authority	Service Desk	Excel / JIRA	GR	JIRA is a communication system. No procedures are changed. Oracle and FRACAS nr are used. JIRA is an interim tooling. Whenever an issue is registered there is a need for what it is: Re-pair/Spare/Technical Issues/Other Also a link with identification and Equipment
	H	2	Data Transfer to Service Desk	System Access	Deferred	on demand	Other	Service Desk	Local Ad Hoc	RadS	Data transfer of the data itself, but also the access log. In this way there is a registration who or what had access to the system and also what actions have been done, remotely or on the spot with a maintainer terminal
	H	1	General Binaries	System Status	Deferred	on demand	WFE	Service Desk	Local Ad Hoc	RadS/ EW	When the asset (ship or land based system) is accessible for the WFE, he will retrieve the HDD and upload the binaries via FTP to Thales Nederland. This is a large amount of information, actually all information that is logged during use.
	I	1	Remote Diagnostics / Access	System Control	Real time	none	Other	Other	Local Ad Hoc	RadS/ EW	This also has influence on the system access. Executed to analyze failures and solve urgent issues. This includes: - System monitoring - Remote Reset - Local Reset via Maintainer Terminal This remote access will not be done by Service Desk! Always by an (WF) Engineer and / or by the OLM on site! And after permission by the com-mander on scene.
	I	2	Remote Software update	System Control	Real time	on demand	Other	OLM	COMA	RadS	Software update of the asset, when direct (physical) access is not possible. Only triggered by an event.

Appendix B

Survey Questions

title	question	help	mandatory	question order
A1	Error files		Y	0
A2	Event logs		Y	1
A3	Defect Report / Intervention Form		Y	2
A4	LRU information	All LRU information. Data that can be downloaded separately from the rest of the system.	Y	3
A5	Operational Data Logging	All operational data!	Y	4
B1	Life / Operating hours		Y	5
C1	Condition Based Monitoring data		Y	6
C2	Temperature	Temperature from several sensors, internal and external	Y	7
C3	Environmentals	All environmental information excluding GPS information	Y	8
D1	Configuration Information		Y	9
D2	Items to be tracked by serial number		Y	10
D3a	Equipment	Also known as system identification, highest level of breakdown.	Y	11
D3b	Identification	First level of breakdown	Y	12
E1	System Status	Status of MSI, deferred	Y	13
E2	Operational System Status	Online / Real-time	Y	14
E3	Health Report		Y	15
F1	Non automated data	Really general subject but if PBL is going to be implemented or contracted on systems already in use, one has to take into account that not all the needed information is available electronically.	Y	16
G1	Maintenance planning		Y	17
G2	Maintenance Report		Y	18
G3	Issue registration	Registration of Issues reported at the service desk	Y	19
H1	Data transfer to Service Desk	The act of transferring the data to the Service Desk, including the access-log. 	Y	20
H2	General Binaries	Large amount of data, actually all data that is logged during use.	Y	21
I1	Remote Diagnostics / Remote Access		Y	22
I2	Remote software update		Y	23

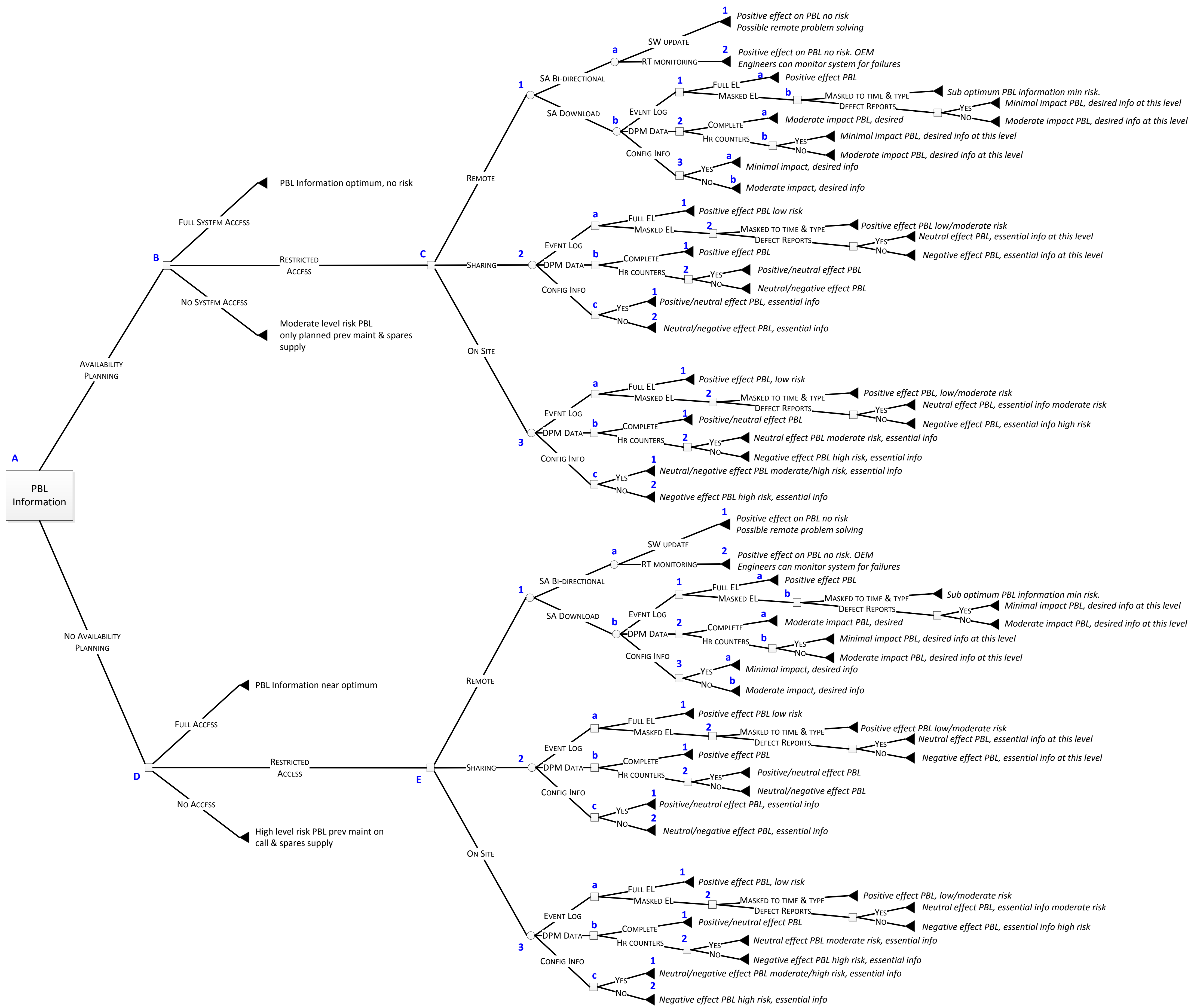
APPENDIX C

Survey Results

Achter-naam	Non auto-mated data	Opera-tional (tech-nical) Data Logging	LRU infor-mation	Defect Re-port	Eventlogs	Error files	Life / Operat-ing hours	Environmen-tals	Temperature	Condition Based Moni-toring data	Identification	Equipment	Configura-tion Infor-mation	Issue regis-tration	Maintenance Report	Data transfer to Service Desk	Remote software update	Remote Di-agnostics / Remote Ac-cess
Score	11	8	6	6	7	9	5	8	7	8	4	4	5	6	7	6	9	7
RY	Desired	Optional	Desired	Essential	Desired	Desired	Essential	Desired	Desired	Desired	Essential	Essential	Essential	Essential	Desired	Essential	Optional	Desired
RadS	Optional	Essential	Essential	Desired	Essential	Optional	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Essential	Desired	Essential
EW	Optional	Desired	Essential	Essential	Optional	Optional	Essential	Desired	Desired	Desired	Essential	Essential	Desired	Optional	Optional	Optional	Essential	Essential
GR	Optional	Desired	Desired	Desired	Essential	Essential	Desired	Optional	Desired	Optional	Essential	Essential	Essential	Essential	Essential	Essential	Optional	Optional
Score	11	8	6	6	7	9	5	8	7	8	4	4	5	6	7	6	9	7

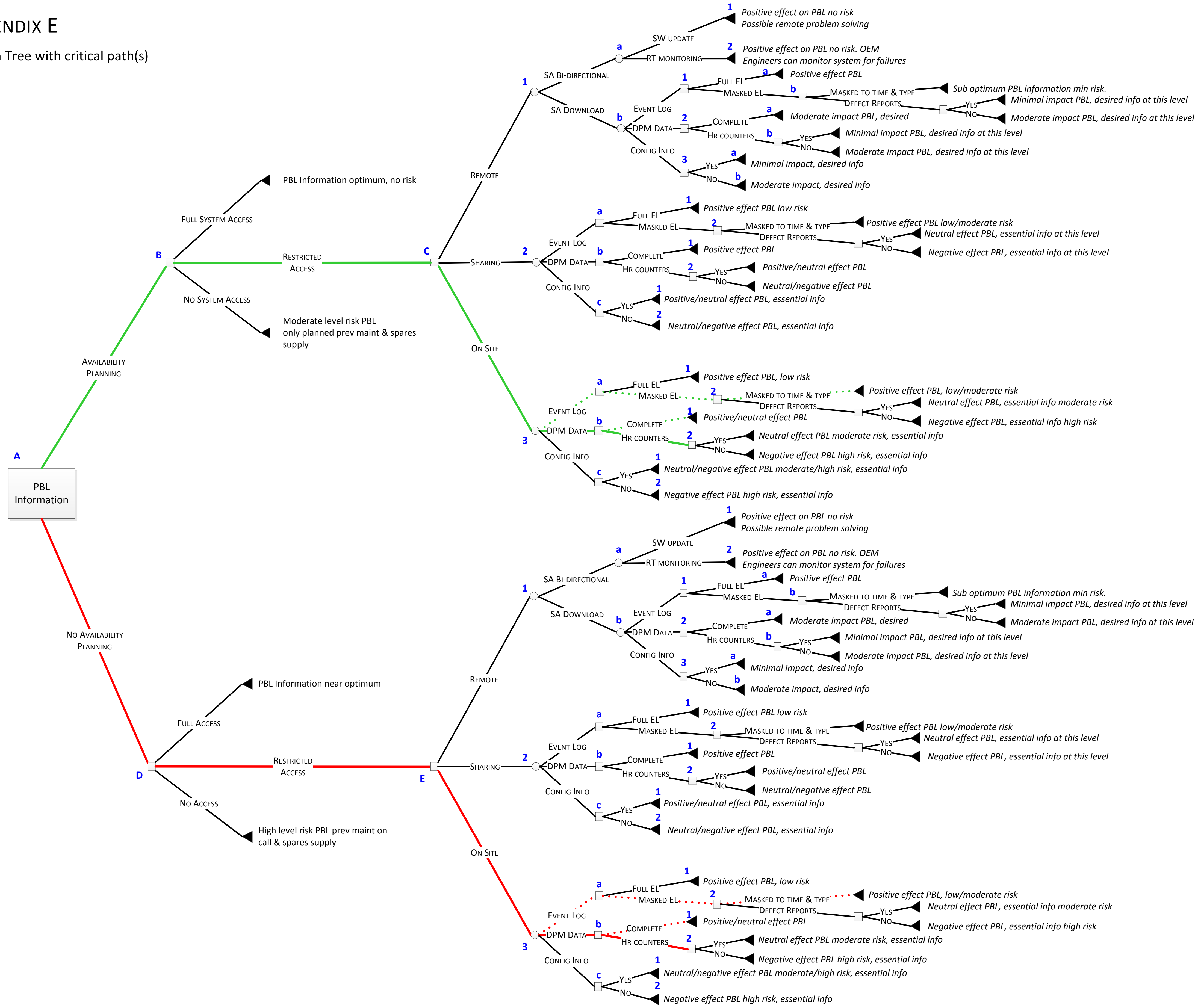
Appendix D

Decision Tree



Appendix E

Decision Tree with critical path(s)



Appendix F

Node					Explanation	Consequence on PBL: Cost	Consequence on PBL: Availability
A					Information of a system available during the contracted period. The other nodes will have more details about the break down	+	+
B					Planning information concerning system use (training or deployment) available. The extremes Full System Access (++) or No SA (--), are not further discussed. Full SA results in an information optimum and No SA results in a preplanned maintenance schedule with a higher risk on availability.	+	+
C					Restricted Access to the system, this implies that conditions are set to be able to acquire the needed information. Planning info available. The Restricted Access is split in Remote, Download and Sharing.	+	+
	1				Remote; i.e. the connection to the system can be initiated from TNL, but has to be approved at the system side. It also implies that remote changes to the system are possible.	+/-	+
		a			Bi-directional; hence two way information traffic (remote can be expensive)	-	+/-
			1		SW update; software update during deployment	+/-	+/-
			2		RT Monitoring; real-time monitoring of the system to analyze failures	+	+
		b			Download; only one way traffic.	+	+
			1		Event log (EL) essentially all logged information is available	+	+
				a	Full EL; all logged information	+	+
				b	Masked EL; partial logged information, pre-determined	+/-	+
			2		DPM data; information related to maintenance	+	+
				a	Complete; when available	+	+
				b	Hr Counters; when available	+	+
			3		Config info	+	+
				a	Available	+	+/-
				b	Not Available	-	-
	2				Sharing; the information is shared by the customer, one direction	+	+
		a			Event log (EL) essentially all logged information is available	+	+
			1		Full EL	+	++
			2	a	Masked EL to time and type	+/-	+
				b	Defect Reports	+/-	+
		b			DPM data; information related to maintenance	+	+
			1		Complete	+	+
			2	a	Hr Counters available	+/-	+
				b	Hr Counters not available	-	+/-
		c			Config info	+	+
			1		Available	+/-	+/-
			2		Not Available	+/-	+/-
	3				On Site; implies pre and post-deployment checks	+	+
		a			Event log (EL) essentially all logged information is available	+	+
			1		Full EL	+	++

			2	a	Masked EL to time and type	+	+/-
				b	Defect Reports	+/-	+/-
		b			DPM data	+	+
			1		Complete	+	+
			2	a	Hr Counters available	+/-	+/-
				b	Hr Counters not available	-	-
		c			Config info	+	+
			1		Available	+/-	+/-
			2		Not Available	-	+/-
D					Planning information concerning system use (training or deployment) not available. The extremes Full System Access (++) or No SA (--), are not further discussed. Full SA results in an information optimum and No SA results in a preplanned maintenance schedule with a higher risk on availability.	-	-
E					Restricted Access to the system, this implies that conditions are set to be able to acquire the needed information. No planning info available	+/-	+/-
	1				Remote; i.e. the connection to the system can be initiated from TNL, but has to be approved at the system side. It also implies that remote changes to the system are possible.	+/-	+
		a			Bi-directional; hence two way information traffic (remote can be expensive)	-	+/-
			1		SW update; software update during deployment	+/-	+/-
			2		RT Monitoring; real-time monitoring of the system to analyze failures	+	+
		b			Download; only one way traffic.	+	+
			1		Event log (EL) essentially all logged information is available	+	+
				a	Full EL; all logged information	+	+
				b	Masked EL; partial logged information, pre-determined	+/-	+
			2		DPM data; information related to maintenance	+	+
				a	Complete; when available	+	+
				b	Hr Counters; when available	+	+
			3		Config info	+	+
				a	Available	+	+/-
				b	Not Available	-	-
	2				Sharing; the information is shared by the customer, one direction	+	+
		a			Event log (EL) essentially all logged information is available	+	+
			1		Full EL	+	++
			2	a	Masked EL to time and type	+/-	+
				b	Defect Reports	+/-	+
		b			DPM data; information related to maintenance	+	+
			1		Complete	+	+
			2	a	Hr Counters available	+/-	+
				b	Hr Counters not available	-	+/-
		c			Config info	+	+
			1		Available	+/-	+/-
			2		Not Available	+/-	-
	3				On Site; implies pre and post-deployment checks	+	+

a			Event log (EL) essentially all logged information is available	+	+
	1		Full EL	+	++
	2	***a***	Masked EL to time and type	+	+/-
		b	Defect Reports	+/-	+/-
b			DPM data	+	+
	1		Complete	+	+
	2	***a***	Hr Counters available; bare minimum on information	+/- -	+/-
		b	Hr Counters not available	--	--
c			Config info	-	-
	1		Available; although available, more info is needed to perform on a higher level	+/-	-
	2		Not Available	--	-