Performance measurement in small to medium sized development projects

A case study applying Earned Value Management on development projects at Swedish Space Corporation

Ylva Houltz
Abstract

To measure performance in a small to medium sized project is not always an easy task. The effort of compiling and presenting data must be related to the total amount of man-hours allotted to the project. This means that the performance measurement often is limited to a monthly check that the project cost has not exceeded the total budget. In this way the project manager has little means of judging if the project really is on schedule. Neither is any forecasting on the projects ability to finish in time or on budget possible.

The scope of this thesis is to apply the Earned Value Management Method to the projects developed at P&R SSC, and to suggest a pragmatic approach to perform this. Historical data on a real project performed at SSC are used to validate the method.

The conclusion is that Earned Value can be implemented. All data needed is already at hand, but some adaptations in the way projects are planned need to be done. It is shown that the method will provide additional information on the project progress during execution. In addition some visual indicators are suggested in order to improve understanding of the project performance situation when reporting to Project Owner, Management and Steering Group.

Note: To achieve optimal readability of graphs and figures in printed version the author recommends using a colour printed copy.
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1 Introduction

This chapter contains the background of this thesis and a justification of the topic selected to be studied. The limitations of the study are stated and the research questions to be answered are formulated.

1.1 Background

This master thesis is written in the frame of the program "Project management and Operational Development" at the Royal Institute of Technology (KTH) in Stockholm, Sweden. I have participated in this program as a part time student for a couple of years, in parallel to my ordinary work as a systems engineer and project manager at the Payloads and Rockets Department in the Science Services Division at the Swedish Space Cooperation, SSC.

The reason to select the topic "Performance Measurement" for my thesis is that recently an increased demand for regular reporting of cost development and project progress from the accounting functions in the company has been seen. This calls for a more formalised way to track project performance and improve forecasting, also on the sub-project level. Tools and routines that can give an image of the cost and time situation without adding too much overhead are needed. It was therefore interesting to make an investigation on possible tools and techniques to achieve this, and specifically the possibility to implement the Earned Value Method, which had been covered in the course curriculum. The availability of project data from real commercial projects and my insight in the procedures and support systems available at the workplace made it possible to gain results that would also in the end be of use in the daily work at the department.

1.2 Problem definition

During the duration of a project it is essential for project owners and project managers to be able to assess if the project is on schedule and on budget. This is often only performed by taking a quick check that the project cost has not exceeded its budget and that activities seem to be on plan.

This approach only gives a momentary image of the situation. No information on the projects ability to finish in time and within the budgetary limitations is at hand. This may lead to unpleasant surprises like late deliveries or cost overruns. Or on the other hand, over-commitment of resources may lead to unnecessary early deliveries in one project, when these resources could have been better used in other projects.

For a large cooperation and large projects it is possible to prevent this by appointing specialists to continuously review the project portfolio, but for a small organisation that kind of resources are not available.

The scope for this thesis is to suggest ways to implement performance measurement in small and medium size projects in such a way that the momentary situation can be assessed at any time during the project life-cycle, giving the possibility to change resource and budget allocations early and secure a timely delivery at the required quality level.

In small to medium sized projects the project manager’s time for progress measurement is often limited, and this factor must also be taken into account. The tools and processes suggested must be able to automate in such a way that the analysis can be performed and updated regularly with minimal effort. Only a light-weight procedure is likely to win acceptance.

The Earned Value Method is a widely used method to achieve progress measurement and forecasting.
It has been selected as the main tool to be evaluated in this study.

The Payloads and Rockets (P&R) department at Swedish Space Corporation (SSC) is used to evaluate the suggested methods and tools. These will be tailored to the needs and environment of this department. Data from a historical project will be used to assess if the suggested methods improves the information on the project progress, compared to what was understood at the time it was performed.

Due to the limited staff available continuous performance measurement during projects is limited. The parameters measured are only cost as related to budget and time schedule fulfilment, but without correlation. This makes it hard to get a correct picture of the over-all project performance during the project, since an under-performing project with high costs can appear as it is on schedule.

It would be beneficial if performance could be measured continuously during projects. This would facilitate the possibility to find possible overruns and schedule slippages as well as unintended scope changes at an early stage. This must however be done in such a way that it does not demand significantly increased workload for the project managers.

### 1.3 Large and a small projects

This thesis deals with the specific environment of small and medium sized projects. So what is a "small", "medium" and "large" project?

This question is probably answered differently in each organisation, depending on the nature of its activities. The Swedish Transport Administration has a limit for "small" projects at 4 billion SEK.

The NASA EVM implementation Handbook (NASA, 2013) which has the following categories (not called small-medium-large), here also the need to use EVM is described:

<table>
<thead>
<tr>
<th>Budget</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Budget SEK</strong></td>
<td>0-120 Mkr</td>
<td>120-300 Mkr</td>
<td>300+ Mkr</td>
</tr>
<tr>
<td>EVM</td>
<td>Non EVM, performance management</td>
<td>EVM</td>
<td>EVM</td>
</tr>
<tr>
<td>Sub-contractors</td>
<td>Non EVM, performance management</td>
<td>EMV, compliance</td>
<td>EVM, validated</td>
</tr>
</tbody>
</table>

For the environment described in this thesis the scale is a bit smaller and the following criteria may serve:

<table>
<thead>
<tr>
<th>Time</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 1 years</td>
<td>1-3 years</td>
<td>3+ years</td>
</tr>
<tr>
<td>Team</td>
<td>&lt;5</td>
<td>5-20</td>
<td>20+</td>
</tr>
<tr>
<td>Budget</td>
<td>&lt;5 Mkr</td>
<td>5-50 Mkr</td>
<td>50+ Mkr</td>
</tr>
</tbody>
</table>
Which challenges are seen in a small project compared to a larger one? The experiences after having participated in an number of projects in different scales and run by different companies can be compiled as follows:

<table>
<thead>
<tr>
<th></th>
<th><strong>Small</strong></th>
<th><strong>Large</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Personnel</strong></td>
<td>Only few resources available. Very dependent on the skills and availability of actual person.</td>
<td>More persons with similar skills available. Tasks can be split between multiple persons.</td>
</tr>
<tr>
<td><strong>Infrastructure</strong></td>
<td>Co-location possible facilitating informal information flows</td>
<td>Resources may be divided into multiple workplaces, more demand for formalized communication</td>
</tr>
<tr>
<td><strong>Budget</strong></td>
<td>Even a small mistake or disturbance may cause a large overrun in percentage of the total budget</td>
<td>A large budget is less sensitive to small mistakes</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>Delays are more easily detected, and can sometimes be remedied by adding more resources.</td>
<td>Delays may not be easily detected and when found cause large deficits</td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td>Possible for one person to manage whole project scope.</td>
<td>In very large projects it can be hard to ensure that all sub-projects meet the intended scope. Multiple levels of management are needed.</td>
</tr>
</tbody>
</table>
1.4 Questions to be answered by this thesis
The focus of this thesis is to suggest an improved method for assessment of the actual project situation, for trending and for post-project evaluation for projects conducted at P&R department at SSC. Earned Value Management is a widely used method to achieve this and is therefore selected as the object of study. Descriptions of the method and its implementation are found in the following references: (Philipson & Antvik, 2009), (Antvik, 2013), (Antvik & Sjöholm, 2012) and (PMI, 2009).

Hence the main question to be answered by this work can be formulated as:

**How can the Earned Value Management method be applied for the projects run at P&R SSC?**

To answer this some corollary questions need to be answered:

Corollary questions:

1. Do the stakeholders (management, project managers and steering group) see need for improvements in project follow-up and forecasting?
2. Would an improved forecasting of project performance improve the possibility to finish projects timely, i.e. by adding more resources?
3. Can the suggested method be implemented in such a way that its application does not cost much more manpower to maintain?
4. Will the additional effort of understanding and applying a new method find acceptance by the project managers and the department managers?
5. Does the available data fulfil the needs for an analysis of the project progress or must more or different data be collected?
6. Can the same data be used to show other project metrics that are of interest?
7. Can early warnings on schedule and/or budget slippage be detected when applying historical data?

1.5 Rationale
This study may be of interest both for the directly involved stakeholders, but also for anyone interested in improving the project metrics and forecasting in a similar organization. It can also be useful for researchers and students looking for empirical evidence from recent project management activities.
2 Method

>This chapter contains the scope of the study, and a description of the different parts. The objectivity, validity and reliability is discussed, as well as the tools and sources of data to be used.

2.1 Scope of the study

Working with small projects of a limited duration requires a different organisation compared to working with more extensive projects. Due to the limited project budget in terms of cost and time the resources for management are limited. The cost for management can not extend to more than a certain percentage of the total project budget. This means that the effort of planning and performance measurement is limited. The project team consists of only a few persons that have to fill all the roles and specialities needed within the project, sometimes with an addition of external resources on short duration.

This situation causes both benefits and difficulties:

- The small number of project stakeholders makes communication easy. Many problems can be solved by walking over to the person involved and having a short discussion.

- A limited number of involved personnel mean that no one can devote much time for planning and performance measurement. Although the necessity of these tasks is understood, they are easily neglected in situations where peaks in workloads appear.

- An organisation performing small to medium sized projects may not see the need for structured project management. Having performed similar tasks multiple times makes the project managers confident in their tasks, but can also cause changes in the project environment go unnoticed, causing unplanned changes in project scope.

- Highly skilled specialists may not see the need for and express interest in the economic side of a project. It is therefore essential for a project manager to be able to communicate the project situation in an easily understandable way to facilitate good decisions in the project team.

The aim of this study is to analyse the project management at P&R SSC to see if possibilities to improve the project management procedures and specifically the performance measurement in such a way that it can win acceptance in the organisation and not be perceived as an additional burden of little value.

The study will focus on the aspect of the cost and schedule control in project performance measurement. It will not address the control of technical results "product quality" or resource planning of projects. No study of alternative software tools to implement the suggested improvements will be made.

This study is performed in the form of a case study. Only the projects performed at P&R department will be studied, and the study will follow the project development process used at the department.

Although the project environment and customer requirements for projects conducted at P&R may be different from other companies, the main project management process does not differ from the "good practice" employed in organisations of different sizes and business sectors. It is therefore the author’s sincere hope that this study can serve as an input and baseline for similar discussions in other organisations and companies.
2.2  The objectivity, validity and reliability of the study
To ensure that the study will result in something useful its validity and reliability must be discussed, and also the objectivity of the author. These concepts can be described as follows:

Objectivity: Is the author free-standing from the studied object?

Validity: Does the study really describe the phenomena that it claims to study?

Reliability: Are the conclusions drawn from the study possible to apply to other, similar, topics with the same results?

2.2.1  Objectivity
I have myself been working in the organisation since 2001, both as a project manager and project team member. This means that I cannot apply a totally objective point of view on the situation, something that should be taken into account by the reader when reading this text. On the other hand the long experience of the organisation and the challenges met in the projects, can enable a deeper understanding of the processes determining the success factors in the project management. In this way the study can benefit of a deeper knowledge of the working environment, the processes and the historical perspective. It is also beneficial in the way that access to and selection of interesting data is granted in a way that would have been hard to get for an external reviewer.

The type of study can be regarded as "participating observation" (Yin, 2003).

To ensure that more than one point of view is expressed in this study interviews with colleagues in different positions in the project control structure has been held. The input from them also serve as an indication on the satisfaction with the current status, the perceived need for improvement and the willingness to adapt to new ideas.

2.2.2  Validity
The "10-step method" developed at FMV is selected as a tool to measure the maturity of the project environment. In this way this can be directly compared to other companies and organizations (Antvik, 2013) and (Antvik & Sjöholm, 2012).

Since historical data are available these can be used to evaluate the suggested methods. In this way a "playback" of the historical project can be achieved and the results using the suggested methods be directly compared to the situation during the project execution.

2.2.3  Reliability
The ideas and concepts discussed in the study will be integrated and tested in the daily work at SSC. In this way their reliability will be tested in the same environment as they are intended to be used. Since the work is performed as a part-time study, and thus expanding over a longer time than normal for full-time students, the reliability of the suggested methods can be evaluated in the everyday activities in parallel with the study. In this way an early detection of elements that are not applicable to other projects of the same type can be made and the study corrected accordingly.
2.3 The elements of the study

In order to be able to answer the questions posed in chapter 1 different aspects of the project environment must be explored: Is the project environment and project management process mature enough to support structured project evaluation? Are all data needed found and easily retrievable from the support systems? Are the users/stakeholders willing to accept new methods?

Also the feasibility of adapting the Earned Value method and other suggested tools should be validated by applying them to the actual data available in order to assess if they will give a reliable image of the project progress that can be communicated to the stakeholders.

In order to cover these aspects the following activities has been designed:

1) Interviews of the three main stakeholders in relation to project performance measurement. These interviews intend to show:
   - The attitude towards project performance measurement
   - Satisfaction with current situation
   - Perception of need for improvement
   - Willingness to adapt to new methods

2) Analysis of the project management process at P&R
   - Study of an actual project
   - Comparison to the 10-step model

3) Adaptation of Earned Value Management to the project process of P&R
   - Suggestion of criteria for Earned Value calculation
   - Implementation of parameters for project performance tracking
   - Implementation of parameters for project forecasting

4) Suggestion on other parameters possible to use to keep track of project progress

5) Validation of model by application of historical data

2.3.1 Interviews on performance measurement

One of the main obstacles in implementing new methods in an established workflow is attitude in the people that shall use them. To start using a different way of working takes some energy: First to see the need for the new method, secondly to learn how to apply it and third to be willing to sacrifice the added effort. When time and resources are limited it is easy to return to using old and well established ways of working, unless substantial benefits are seen in using the new method.

A series of interviews are planned in order to see the satisfaction with the current situation, the need for improvement and to assess the willingness and interest to adapt to a new way of working. The three interviewees are selected to represent different views of the project stakeholders.

- **Sub-project manager**: This person is responsible for the monthly accounting of cost and progress for his/her sub-project. This reporting consists of a manual collection of data on man-hours and money spent from the accounting system, plotting the data in a graph, comparing them with the planned budget and writing a project report summarizing the project status. Symbols, “traffic lights”, are used to give the sub-project managers view of the timeliness, performance and budget of the sub-project.
- **A main project manager:** The main project manager compiles all the reports from the sub-projects to get an image of the total project situation. Having 4-6 sub-projects the project reports are essential to get the full picture of the project progress and to be able to move resources where they are needed.

- **A project owner:** The steering group is the project owner and a forum for evaluation of the project. Since the timely delivery of the project is the highest priority the steering group must see that no schedule slippages appear in any of the sub-systems and rearrange or provide additional resources if that should happen.

The interviews are held as guided dialogues following a questionnaire (see appendix 1) with open questions (Yin, 2003) and (Cottrell, 2014). The interviews are held in Swedish, transcribed and translated into English. The written translation will be reviewed by the interviewees before being published, to ensure that the information is correctly understood and interpreted by the interviewer.

### 2.3.2 Analysis of the project management process

An analysis of the project management process is performed to see if it fulfils the 10-step model as described in the literature (Antvik & Sjöholm, 2012) and (Antvik, 2013). The reason for this is to see if all pre-requisites for performance analysis are at hand, and to be able to determine the factors that can be used to measure the Earned Values in the projects.

The following data will be used as input to the analysis:

1. Management system: The process "Sub-orbital project development" contains all information on the management of development projects within P&R.
2. Project information from one project recently performed at P&R. No specific selection criteria will be applied.

### 2.3.3 Adaptation of Earned Value Management to the project process of P&R

According to the conclusions found in the analysis of the project management process, the needs for changes/and or improvements in order to implement the Earned Value Management method will be discussed.

### 2.3.4 Validation of model by application of historical data

In order to see if Earned Value Management can be shown to predict project progress better than the assessment of experienced project managers an analysis of historical data on a sub-project will be performed.

**Tools:**

An excel sheet will be set up to perform the actual analysis. This sheet will contain:

- The data extracted from the accounting system
- A graph outlining the intended project budget consumption
- A graph outlining the actual project flow as seen during the project
- A graph using the same data but also using EVM to assess project progress.
Inputs:

1. Project plan: This document states the intended schedule, budget and resources assigned to the project. (SSC, Project Plan XRMON-SOL B-phase, 2013)

2. Project preliminary budget: The preliminary budget is the data used as input to the quotation to the customer. This document contains all calculations of manpower and direct costs for each work-package in the (sub) project. (SSC, XRMON-SOL Förkalkyl och kostnadsuppföljning, 2014)

3. Project data from the accounting system: For each month the actual resources used in man-hours work cost and direct cost will be extracted from the accounting system and noted in a table.

4. Project reports compiled during the project. These projects contain the project manager’s perceived opinion on the project progress. (SSC, Månadsrapport XRMON-SOL, 2014)

2.3.5 Database

All the data will be extracted from the company document handling and accounting systems. All data used will be stored in a local file system, to ensure availability during the progress of the work.
3 Literature

This chapter contains the theoretical background information acquired from the literature study. First the 10-step model is presented, and then the Earned Value Method and its history are described. The phases needed to implement the Earned Value method are also outlined. The sources referenced are listed under "References" in the end of the document.

3.1 The 10-step model

The 10-step model was invented by FMV in 1993, (Antvik, 1999) and (Antvik, 2013). It contains all steps needed to plan and perform a project. It is useful to determine the maturity of a project management process, by checking if all the steps have been implemented.

Of the ten steps the six first are related to project planning and the following four to the execution phase.

The 10 steps are:

<table>
<thead>
<tr>
<th>Step</th>
<th>Name</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project goals</td>
<td>The definition of the task or goal that the project aims to fulfil.</td>
</tr>
<tr>
<td>2</td>
<td>Work Breakdown Structure (WBS)</td>
<td>A structured break-down of all tasks and activities that shall be carried out in the frame of the project.</td>
</tr>
<tr>
<td>3</td>
<td>Organisational structure (OBS)</td>
<td>A structured break-down of all parties involved in the project execution such as departments and sub-contractors and their relations.</td>
</tr>
<tr>
<td>4</td>
<td>Responsibility Assignment Matrix (RAM)</td>
<td>A description of who is responsible for what during the project, and the reporting chain and procedures.</td>
</tr>
<tr>
<td>5</td>
<td>Schedule</td>
<td>Planning of activities, deliveries and milestones. A Gantt plan is often used for this, but it can also be done in other ways. A critical chain analysis to see minimum project duration can also be included.</td>
</tr>
<tr>
<td>6</td>
<td>Budgeted Cost for Work Scheduled /Preliminary Budget (BCWS or PV)</td>
<td>A plan for the project budget and its spending over the project execution time.</td>
</tr>
<tr>
<td>7</td>
<td>Actual Cost of Work Performed (ACWP / AC)</td>
<td>The actual costs for manpower and materials, as invoiced during project execution. Preferably checked at regular intervals.</td>
</tr>
<tr>
<td>8</td>
<td>Results/Deliveries</td>
<td>Checking which activities that are fully completed. This should be ticked off at a regular basis.</td>
</tr>
<tr>
<td>9</td>
<td>Budgeted Cost for Work Performed / Earned Value (BCWP / EV)</td>
<td>Compilation of the budgeted value of the activities that have been completed up to now.</td>
</tr>
<tr>
<td>10</td>
<td>Analysis of actual situation and Trending</td>
<td>The compiled data is used to assess the project status with regards to schedule and budget, the efficiency of the work process and to compile a forecast of date for finalisation and final cost (Estimate At Completion, EAC).</td>
</tr>
</tbody>
</table>
3.2 The Earned Value Management method (EVM)

3.2.1 History of Earned Value Management

The Earned Value Method was invented in the USA in the early 1960’s as a way to keep track of government funded defence projects. The reason was that large overruns were seen in some projects and a method to judge the performance was needed. Usage of improved planning techniques had already been established, both the basic Gantt chart and the more advanced network planning methods CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique) (Antvik, 2013).

An increased demand for the ability to track not only the schedule but also the budget performance of projects caused the PERT method to be further developed into PERT/COST. This was later extended to also take the value of the work delivered into account, the Earned Value. This was called Cost/Schedule Performance Control Specification (C/SPCS). The US Department of Defence required its contractors to use the method, but it was considered difficult to implement and inflexible by many.

Over time the method evolved into EVM and was more widely adopted, also outside the defence industry. The availability of computers has probably played a large role in this, since the effort of calculating and compiling data became more manageable when more computing power became readily available.

Earned Value Management is now required by a number of US governmental agencies. The method has been standardized in the USA as ANSI EIA 748-A and as AS 4817-2003 and AS 4817-2006 in Australia. For example, NASA requires an ANSI/EIA-748 compliant Earned Value Management System (EVMS) for all contracts exceeding $20 million. (NASA, 2013)

In Sweden the first large-scale implementation was made during the JAS-Gripen project (Antvik, 2013).

Earned Value Management was included in the PMBOK Project Management Body of Knowledge in 1987 (PMI, 1987), and has been improved in later editions (PMI, 1996), (PMI, 2000), (PMI, 2004), (PMI, 2009) and (PMI, 2013). It is now used in many areas.

3.2.2 Description of the method

The distinguishing idea behind the Earned Value Management method is to continuously measure the actual deliverables achieved in the project and compare them to the planned progress. Thus a pre-requisite for the application of the method is that a suitable set of deliverables can be defined and met during the project lifetime. These deliverables can be of different types in different areas such as the foundation of a house, a breadboard model of a new product or a passed user acceptance review. Besides the deliverables a project baseline including the planned schedule/duration and budget is needed. During project execution the amount of completed deliverables at any specific time can be compared to the original plan, and the result be used to compile an assessment of the project status in terms of cost and schedule effectiveness. Extrapolating these values can be used to compile forecasts of the total project duration and final cost. (PMI, 2009).
3.2.2.1 Prerequisites
To be able to implement the Earned Value method the project need to have a defined baseline. The three factors that must be decided are:

- What shall be done (scope)
- When shall it be delivered (time schedule)
- What is the cost limit (budget)

These three factors can be described by performing the steps 1-6 in the 10-step model.

3.2.2.1.1 Scope
The contents of the project shall be defined. This can be done in different ways, a common practice is to arrange the Activities to be carried out into Work Packages.

All planned project work should be arranged in a way so that it can be "delivered" to the project as packages during the execution time. This means that large tasks my need to be split into sub-parts. A criterion for "completed" status must be agreed for all tasks.

3.2.2.1.2 Schedule
A fixed time schedule, containing at least the project start and finalization dates, must be decided. Also the time-boxes for project evaluation should be decided already on project start, either as fixed duration points or as project milestones.

3.2.2.1.3 Project budget
The project must have a defined budget, and this budget must be possible to divide over the project schedule. In its simplest version the budget can be divided with equal portions for each time-box. In a more detailed project plan the resource plan may vary over the project execution cycle and this should then be reflected in the budget plan. An accurate reporting of the current budget spent (in currency and/or man-hours) must be available during the project execution, and be possible to correlate to the time-boxes for project reporting.

When tasks are performed by sub-contractors the scope, schedule and budget is commonly determined by a contract. The organisation of work delivered by sub-contractors is described in step 3 and 4 (Organisational Breakdown Structure and Responsibility Assignment Matrix).

3.2.2.2 Basic concepts
The basic factors for the project evaluation are:

**Planned Value [PV or BCWS]:** The planned budget consumption for the project up to the current date/time-box. (Step 6)

**Actual Cost [AC or ACWP]:** The budget consumed up to the current date. (Step 7)

**Earned Value [EV or BCWP]:** The value of all the completed tasks up to the current date. (Steps 8 and 9)

**Budget At Completion [BAC]:** The total budget for the project, until project end. (Step 6)

**Estimate At Completion [ EAC]:** The estimated final cost for the project (Step 10)

In this report the dominations PV, AC and EV will be used throughout for clarity.
A graphical presentation of these concepts is shown below:

![Graphical presentation of the concepts described above (GAO, 2009)](image)

3.2.2.3 Performance tracking

The performance of the project execution at any time during the project cycle are described by comparing the intended process to the actual progress. The following indexes can be used to follow the progress compared to the intended budget consumption and to the planned schedule. In order to enhance the usability two different perspectives can be used (Humphreys & Associates, 2010):

**Efficiency perspective:** "For every dollar spent I earned x dollar of work". If the index is larger than 1 you have paid less than planned for the work produced. This perspective show how efficient you are using your funding. (The efficiency of the working capital is more than 100% compared to plan.)

The indexes show the efficiency of the execution of schedule and budget. This is useful to describe the current situation regarding work effort and budget utilisation. This version is often used in international literature (PMI, 2009)

**Performance perspective:** "For every dollar work accomplished x dollar was spent" If the index is lower than 1 you have produced more value for your money than planned.

The indexes can be used to directly calculate estimates of project final cost and schedule by multiplying the BAC with the Cost Performance Index and Duration with the Schedule Performance Index. This is very useful to give a forecast of the final cost and duration. (Philipson & Antvik, 2009)
In the following paragraphs the indexes "p" for performance perspective and "e" for efficiency perspective are used to distinguish between the two versions.

3.2.2.3.1 Variance from planned performance
By comparing the Earned Value to the Planned Value and to the Actual Cost a picture if the current project progress in relation to the plan can be achieved. A graphical presentation of this is found in fig 3.1.

**Schedule Variance [SV<sub>e</sub>]:** The difference between the planned progress and the achieved progress.

\[ SV_e = EV - PV \]

If \( SV_e > 0 \) the project is ahead of schedule, if \( SV_e < 0 \) it is behind schedule. (This variance is expressed in budget, but can be converted to time by comparing it to the cost for man-hours and personnel availability.)

In the performance perspective: \( SV_p = PV - EV \). If \( SV_p > 0 \) the project has achieved more than planned.

**Cost Variance [CV<sub>e</sub>]:** The difference between the Earned Value and the Actual Cost at the current date.

\[ CV_e = EV - AC \]

If \( CV_e > 0 \) the project is within budget

In the performance perspective: \( CV_p = AC - EV \). If \( CV_p > 0 \) the project has spent more budget than planned to achieve the delivered parts.

3.2.2.3.2 Performance Indexes
The same data can also be expressed as performance indexes. These give an indication on the speed and efficiency of the project work and spending. If these indexes are relatively stable they can also be used to compile forecasts on project duration and total costs.

**Schedule Performance Index [SPI]:** This index is used to get an idea of the actual speed in the project.

**Efficiency perspective:**

\[ SPI_e = EV / PV \]

If \( SPI_e > 1 \) the project work is proceeding faster than planned.

The work efficiency is higher than planned.

**Performance perspective:**

\[ SPI_p = PV / EV \]

If \( SPI_p < 1 \) the project work is proceeding faster than planned.

Estimated execution time = Duration * SPI<sub>p</sub>
Cost Performance Index [CPI]: This index describes the financial burn-rate in the project

**Efficiency perspective:**

\[ \text{CPI}_e = \frac{EV}{AC} \]

If \( \text{CPI}_e > 1 \) the project delivers its objectives at a lower cost than planned.

The cost efficiency is higher than planned.

**Performance perspective:**

\[ \text{CPI}_p = \frac{AC}{EV} \]

If \( \text{CPI}_p > 1 \) the project consumes its budget faster than planned, needing more funds than budgeted.

Estimated final cost = cost budget \( \times \) \( \text{CPI}_p \)

### 3.2.2.4 Forecasts

The performance factors can be used to compile an estimate of the final cost and time for completion for the project, thus enabling an early detection of schedule slip and accelerating costs. A forecast of this type is naturally true only if the environment remains the same as during the period the forecast is based on. Such factors as change of staffing and scope-creep can influence the performance and must be regarded. Research show that a cost trend established in about 20% of the project duration seldom improves (Antvik, 2013).

Using the performance factors above an estimate of the total project cost can be calculated as

**Estimate At Completion [EAC]:** The total project cost if progress continues at the current speed.

\[ \text{EAC} = \frac{BAC}{\text{CPI}_e} \]

A couple of alternative ways of calculating EAC exist (PMI, 2009) and (GAO, 2009):

**Estimate At Completion (cumulative CPI):**

This method uses the current SPI to calculate the progress, assuming that the cost performance is consistent over the project execution time.

\[ \text{EAC} = \frac{BAC}{\text{CPI}_e,\text{cum}} \]

**Estimate At Completion (SPI & CPI):**

This method uses both the SPI and the CPI to calculate the progress. This can be used when the cost performance is negative and the project needs to meet at firm schedule. It is also possible to weigh the impact of the two factors.

\[ \text{EAC} = AC + \frac{(BAC-EV)}{(\text{CPI}_e,\text{cum} \times \text{SPI}_e,\text{cum})} \]
**Estimate At Completion (Budgeted rate):**

This method uses the actual performance up to date but assumes that the rest of the project will have performance according to the original baseline. If the actual performance up to date has been less good than originally planned, this estimate may give a poor forecast.

\[ EAC = AC + BAC - EV \]

**Estimate To Complete [ETC]:** This is the estimated cost for the remaining work in the project.

\[ ETC = EAC - AC \]

3.2.2.5 **The remaining effort**

**To-Complete Performance Index [TCPI]:** The TCPI index describe the effort needed to finalise the project. It can be related to either the planned budget BAC or the revised budget EAC.

The effort needed to meet the original budget:

\[ TCPI(BAC) = (BAC-EV)/(BAC-AC) \]

The effort needed to meet the revised budget:

\[ TCPI(EAC) = (BAC-EV)/(EAC-AC) \]

A TCPI > 1 means that the project need to deliver more than planned, but on the same budget as planned for the rest of the planned schedule.

3.2.3 **Implementation of the method**

The implementation of the method is described in several sources. The GAO cost estimation guide provides a thorough advice on the implementation, aimed at larger projects (GAO, 2009). The concept of time-boxes corresponds to the advice in GAO to follow up on EVM at least monthly, but also corresponds well to the agile working concepts of regular "sprints" (Knightech, Seminar 2014-02-18).

3.2.3.1 **Full implementation**

1) Define the work to be performed

2) Assign a value to each activity

3) Define earning rules for each activity

4) Divide the project schedule into time boxes

5) Plan the amount of work to be performed in each time-box

6) Execute the project and measure progress every time a time-box has passed
3.2.3.1.1 The work to be performed
The commonly used method to define the work to be performed is to arrange it in work packages. This can be done by grouping activities that have a limited duration or activities that are of the same type.

An example of limited duration activity could be assembling a prototype. This activity has a starting point and a fixed duration and can span over different specialties such as mechanics and electronics engineering.

An example of activities of the same type could be the management of a project. This activity concerns only one function in the project (which of course can be filled by more than one person) and is active during the whole project duration.

The level of detail in each work package may vary, but activities should not be too long, or they will be difficult to assess both in complexity and in time. Parts of the task are easily forgotten if too large activities are planned. On the other hand the work effort of too detailed planning may not contribute any added insight but rather blur the understanding of interdependencies between tasks. The breakdown level should balance between these two extremes, and be tailored to the needs of the task. Here the input of experienced personnel can be of good use.

3.2.3.1.2 Assign a value to each activity
Activities can be assigned different types of value. Some examples are:

- The number of man-hours planned to finalise the task
- The cost to finalise the task (work hours and cost for materials)
- An amount of "points" that can be based on complexity and/or man-hours

Some tasks may also contain "Direct Cost": costs for materials and services not delivered by the organisation itself. Some of these may be interchangeable with Work Cost, since some work may be purchased from consultants and sub-contractors instead of being performed within the organization. Cost can sometimes be transformed from work hours to direct cost if a work effort can be replaced by acquiring a COTS product. (COTS - Commercial Of The Shelf Product)

A common way of doing this is to let the value for the completed activity be equal to the budgeted cost of the activity. In this way the additional work cost for finding less costly components and for using sub-contractors instead of own personnel can be handled without extra efforts.

3.2.3.1.3 Define earning rules for each activity
The earning rules must also be tailored to the organisation and the task. The easiest way is to let each activity earn its budgeted cost on completion. This only works for limited duration activities, and if applied on limited but long duration activities it will make the progress look slower than it actually is. A variation to this is to let activities earn a percentage of its value already on start, typically 25%, and the rest at completion. This approach improves the delay in the progress measurement somewhat, but there is always a risk that if many activities get started in the beginning of the project, but no progress is made for a long time, a false performance progress is seen and the actual situation is found out too late.

For long duration activities other earning rules must be applied. For example "Management" can be measured as a fixed amount per month during the project, or the actual hours spent up to the budgeted amount. Milestones can also be used as delivery points for long duration activities, in this case it is important to include also the work needed to finalise the milestone, such as compiling minutes of
meetings or closing actions.

3.2.3.1.4 **Divide the schedule into time-boxes**
The project performance tracking should be done at regular intervals. This could be monthly, weekly or at certain project milestones where data is readily available.

The analysis can be done on Cumulative or Period-by-Period basis. It can also be done on the whole project or for sub-parts as convenient, if the appropriate data are available on sub-system level. When analysis is done on sub-system level interdependencies between sub-systems must be taken into consideration.

3.2.3.1.5 **Execute the project and measure progress every time a time-box has passed**
When a milestone is reached or a time-box is completed the achieved results are checked and their "value" calculated. The same is done with the data on project costs. After that performance analysis and forecasts are compiled as described above.

3.3 **Other metrics and methods**
Progress can also be visualised by using other metrics. Two metrics possible to use at SSC are block diagrams showing cost development per work package and Milestone Trend Charts. The Critical Path Analysis is deemed too work-intensive to be possible to keep up to date during the project execution.

3.3.1 **Work-package Block diagrams**
The development of cost in the separate work-packages is a good indication on if problems are developing and can serve as an early warning system. In this analysis the intended duration of the work packages must also be taken into account. It is quite OK for a work package to approach its budget if it is close to completion, but not at mid-duration.

Costs for work-hours and for materials and services (direct cost) should be considered both separately and joined for each work package. Efforts originally planned for in-house workforce may have been replaced by external services during the project. This does not necessarily increase the work-package cost, but may cause cost to be transferred from work hours to direct cost. Thus the actual contributions to the work-package cost must be considered in order to find causes for over or under-runs.

Another thing that can cause these diagrams to have a skewed appearance is the fact that people sometimes report to the wrong work-package. To find this and correct it at an early point is important for the final project evaluation.

If similar division of work into work packages are done for projects of the same type, these graphs can be used to compare the current project performance to projects performed at an earlier point.

3.3.2 **Milestone Trend Chart**
The Milestone Trend Chart is used to visualise if milestone dates can be reached or not. The forecasted date for each milestone is updated regularly and the results are mapped in a diagram that visualises the change in dates during the project. This method provides a good visualisation of timeliness. (Archibald, 2003) and (Cooper, 2014).

At P&R it could be useful on main project level, indicating if there are schedule slippages in the sub-projects that will affect the main project. The chart has been used earlier, for example in the SMART-1 project (Rathsman, Interview 2012-11-27).
A thorough description of the method, together with an Excel implementation is found in (Cooper, 2014).

<table>
<thead>
<tr>
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<td>15-Feb-03</td>
<td>16-Feb-03</td>
<td>22-Feb-03</td>
<td>22-Feb-03</td>
<td>23-Feb-03</td>
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<td>Specification approved</td>
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<td>26-Mar-03</td>
<td>26-Mar-03</td>
<td>31-Mar-03</td>
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<td>20-Apr-03</td>
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<td>6-May-03</td>
<td>6-May-03</td>
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<td>Start of testing</td>
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<td>Final acceptance test</td>
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<tr>
<td>System deployed</td>
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<td>29-Aug-03</td>
<td>29-Aug-03</td>
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<td>29-Aug-03</td>
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<td>29-Aug-03</td>
<td>29-Aug-03</td>
<td>29-Aug-03</td>
<td>29-Aug-03</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3-2: Milestone trend chart (Cooper)

In this version the forecasted date for the milestone is displayed on the vertical axis and the revised dates logged along the horizontal axis for each update. (Archibald, 2003) uses the horizontal axis for forecast and dates for updates on the vertical, latest date at bottom. This corresponds better to the normal directions of the Gantt plans, and might therefore be more intuitive and easier to understand.
3.3.3 Critical Path Analysis

A widely used tool is critical path analysis. In this method interdependences between activities are identified so that the chain of activities that affect the duration of the project can be determined, the "critical path". All the elements in the critical path are dependent on the successful closure of the preceding activity to be able to start its execution. In this way a delay in any of the elements/activities will affect the overall schedule. If activities are completed early the critical path may change, so that another path/chain of activities that previously had more slack becomes critical instead.

Different factors can affect which elements become parts of the critical path. Some factors can be:

- Preceding tasks that need to be completed (You cannot paint the wall before it is erected)
- Availability of resources (If you only have one tester, he cannot be assigned to two units simultaneously)
- Funding (Key items cannot be purchased until a milestone is passed and funding available)
- Delivery times for "long lead items" (units are manufactured on order only)

The critical path information is valuable, but takes a lot of effort to compile and keep updated. It is therefore not recommended to be used on a detailed level, but only for high-level analysis (Archibald, 2003). Because of this it will not be applied in the scope of this study.
4 Survey

This chapter contains information on the company and the project environment, as well as the product development process as described in the Management System and the Problem Area. The 10-step model is used to evaluate the current structure to assess if all data needed to implement Earned Value Management are available. The method is then applied on a historical project, using the concepts described in chapter 3.2.

4.1 Project environment at the P&R department

4.1.1 The company

Swedish Space Corporation is a government owned company that develop and operate space applications. The main business areas are Satellite Communication, Science Services, Technology and Engineering Services. The company owns and operates the ESRANGE rocket base, Vidsel Aeronautical test site and the worldwide Prioranet satellite communication network. The total number of employees is 600, of which 60 work in Solna.

Figure 4-1: SCC organisation (SSC)
4.1.2 Payloads and Rockets department

The payloads and rockets department (P&R) is a part of the Science Services Division. The department develops scientific payloads for research in low gravity and atmospheric research. The payloads are launched on sounding rockets, on board parabolic flights and on high altitude balloons.

The main customers are the Swedish National Space Board, the European Space Organization (ESA) and commercial customers. The workforce in Solna consists of 20 highly skilled engineers and project managers. When needed additional specialists and workforce are hired from consultant companies. The division also includes 40 employees at ESRANGE in Kiruna, working with launching services and instrumentation for rockets and balloons.

4.1.3 Projects executed at P&R

All work except a small amount of department management and internal work is carried out in the form of projects. Project size may vary from a full MASER rocket project containing 5-6 Sub-Projects which normally have duration of one to two years and 4000-8000 man-hours each. But also shorter duration projects down to less than one year duration/ 1000 man-hours are performed. Parts of the work are carried out by sub-contractors in different European countries. The project content is cross-functional and the integrated project teams typically consist of 3-5 persons: A project manager, a system engineer and representatives from electronics, software and mechanics development. Most of the project team members are engaged in more than one project at a time and/or have multiple roles in the project.

Due to the special demands on the projects the most prioritized of the three performance factors: budget-quality-timeliness (Philipson & Antvik, 2009), is timeliness. Since sounding rockets are mainly launched in the periods November to mid-December and mid-January to mid-May a relatively small schedule slippage can cause a rocket campaign to be shifted up to 6 months forward, with additional costs. A hard deadline must be met.

4.1.4 Problem area

Due to the limited staff available continuous performance measurement during the projects is limited. Input to the performance measurement must be manually compiled from the accounting system. No dedicated support system or software for performance measurement exists. The parameters measured are only cost as related to budget and time schedule fulfilment, but without correlation. This makes it hard to get a correct picture of the over-all project performance during the project, since an under-performing project with high costs can appear to be on schedule.

After project finish cost per work package is compiled and benchmarked against project budget and historical data, which provides a historical continuity.

It would be beneficial for the department if performance could be measured continuously during projects. This would facilitate the possibility to find possible overruns and schedule slippages as well as unintended scope changes at an early stage. Considering the extremely streamlined organization this must however be done in a way that does not demand significantly increased workload for the project managers.
4.1.5 The project environment
The projects at P&R are performed according to the “Sub-Orbital Project Development” process in the Management System. This process is developed to fit with the structure imposed by the main customer, ESA, and follows this organisation’s terminology. When applied to the divisions projects the process is scaled according to the needs and size of the project. The project phases are kept but documentation and activities can be reduced when needed. This should be clearly stated in the Project Plan.

4.1.6 The Sub-Orbital Product Development Process
The Sub-Orbital Product Development process is divided in four phases. Input to the process is a Project Directive delivered by the Marketing Group in the Science Services Division. In the main contracts this Project Directive is sometimes replaced by a Request For Quotation (RFQ) issued by the (main) Customer to the Key Account Manager. This RFQ is further elaborated in the Proposal that is returned to the Customer, and which includes the WBS and intended key personnel.

![Figure 4-2: Overview of the Sub-Orbital Product Development Process (SSC, Intranet, 2014-05-10)](image)

The product development process is arranged in four consecutive phases:

A feasibility and definition phase (A/B) containing feasibility studies, product definition and possibly technical evaluation and breadboarding. It is concluded by a Preliminary Design Review meeting.

Design and Manufacturing phase (C/D) where detailed designs are developed and reviewed, the product is manufactured and tested. It is concluded by the Flight Acceptance Review.

Launch and Operations phase (E) containing the preparations for launch, the operation during flight and the handling after flight. It is ended by a Post Flight Meeting.

Post processing phase (F) where post processing of data and delivery to the customer is made, and the equipment is secured for long-time storage.
Figure 4-3: The pre-study phase (A/B) of the Sub-Orbital Product Development Process (SSC, Intranet, 2014-05-10)

In the figure above the details of the A/B-phase are described. Yellow boxes contain descriptions, blue document templates. No procedure for project performance measurement is defined.
4.1.7 Project organisation and reporting

The project organisation consists of a Project Manager, and for the larger projects also sub-projects managers. To ensure the overall performance of the project and the correlation between projects a Steering Group evaluates the project performance regularly.

Project reports are compiled monthly and contain both the budgetary progress and the project managers’ assessment of the project progress.

Figure 4-4: Project organisation for MASER 13 phase B (SSC)
### 4.1.8 Comparison between the Sub-Orbital Project Process and the 10-step model

The 10-step model describes the necessary steps in project planning and execution (Antvik, 2013) page 43. The first 6 steps are related to the planning phase, the remaining four to the execution phase.

<table>
<thead>
<tr>
<th>Step</th>
<th>Name</th>
<th>Implementation at SSC P&amp;R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project goals</td>
<td>Project directive or RFQ from customer</td>
</tr>
<tr>
<td>2</td>
<td>Work Breakdown Structure (WBS)</td>
<td>Included in Proposal. WBS is done both on main project level and for each sub-project. The same structure is preserved between projects in order to facilitate assessment of cost based on historical data and post-mortem comparison between projects.</td>
</tr>
<tr>
<td>3</td>
<td>Organisational structure (OBS)</td>
<td>Included in Proposal. Key personnel appointed to the project are documented in the contract and exchanges need clearance from customer. Sub-contractors are frequently used.</td>
</tr>
<tr>
<td>4</td>
<td>Responsibility Assignment Matrix (RAM)</td>
<td>The responsibilities in the project are described in the main Project Plan. Since the organization is small only the project managers and Sub-project managers are appointed responsibilities, and these are mainly related to accounting.</td>
</tr>
<tr>
<td>5</td>
<td>Schedule</td>
<td>The schedule is an important input to the preliminary budget made before issue of the Proposal. The schedule consists of milestones in form of meetings and reviews with the customer and a Gantt chart describing the intended project flow.</td>
</tr>
<tr>
<td>6</td>
<td>Budgeted Cost for Work Scheduled /Preliminary Budget (BCWS or PV)</td>
<td>In order to be able to issue the proposal a preliminary budget of project cost is made. This is often done in two steps, first a price indication is compiled (ROM-cost), that enables the customer to see if the project can be accommodated within their budget or must be re-scoped. After that a more detailed calculation is performed. This is based on man-hours and direct cost (cost for materials and services).</td>
</tr>
<tr>
<td>7</td>
<td>Actual Cost of Work Performed (ACWP / AC)</td>
<td>The economic results are manually retrieved from the accounting system and compiled on a monthly basis. The results are plotted in a graph and matched to the intended budgetary progress.</td>
</tr>
<tr>
<td>8</td>
<td>Results/Deliveries</td>
<td>Costs and man-hours are accounted for in relation to the Work Package they belong. Meetings and reviews with the customer are important milestones.</td>
</tr>
<tr>
<td>9</td>
<td>Budgeted Cost for Work Performed / Earned Value (BCWP / EV)</td>
<td>A monthly assessment of the project progress is done by the project managers. The Gantt chart is updated and the completed activities are reported in text in the monthly reports.</td>
</tr>
<tr>
<td>10</td>
<td>Analysis of actual situation and Trending</td>
<td>The project progress graph is used by the Main Project manager and the Steering Group to assess the actual situation. At the end of the project the outcome of the work-packages are compared to earlier projects. The final cost per work-package is compared with the budgeted cost and also to the cost for earlier projects.</td>
</tr>
</tbody>
</table>
4.1.9 Available tools

Some software tools are available to enable project follow up and reporting:

**Time reporting:**

All personnel track their work hours weekly in a time-reporting system. The work hours performed is accounted for in the project and work package it has been budgeted in.

**Accounting:**

The company accounting system Agresso contain costs for all work-hours and materials and services that have been invoiced to the project. Data is imported from the time reporting system and updated on a monthly basis.

**Time scheduling:**

The Hansoft software tool is used to compile Gantt charts. This tool also has possibilities for agile planning, or mixed planning.

**Project tracking:**

Data from the accounting system is manually retrieved and plotted in an Excel sheet. This sheet also contains the planned project budget disposition. The Excel sheet is an in-house development and has been gradually improved during the duration of this project, and further extended to contain the tools recommended in this report.

**Resource planning:**

The over-all resource availability is planned in the Silberplan tool. This is mainly available to the department manager and has no interfaces to the other tools.

4.1.10 Planning units

The following planning units are used:

- Project efforts/Project Budget is generally planned in work-hours for labour and SEK for direct cost.
- The accounting system returns cost in SEK for work and direct cost. For work delivered by employees work-hours are also returned. (Consultants are only reported in SEK).
- The payments from the customer are mainly in EURO or SEK.
- Time reporting by the employees is done in work-hours.
- Time scheduling is done in decimal days.

As can be seen in the list above the units differ between the tools. Some additional effort is needed to convert between the units when setting up a project or following up the progress.
4.2 Application of Earned Value on a historical project

To assess if Earned Value management can be implemented in P&R projects a recent sub-project was analysed.

4.2.1 Selection of project

To be possible to determine the Earned Value and project performance factors the following criteria had to be fulfilled:

- The project baseline had to be defined at project start; scope, budget at completion and duration (start and end dates)
- Preliminary budget documented at project start had to be available
- Project reports containing enough data on project progress and compiled reasonably frequently during the execution phase was needed.
- Costs had to be possible to extract from the accounting system.
- The project duration was short so that the calculations could be done within the time available.

The project selected was XRMON-SOL phase B. This project is current, and has a duration of approximately one year. The criteria above are fulfilled, and since the author has participated in the project additional knowledge of the duration of activities could be utilised in addition to the project reports. Two other projects were considered, but had to be rejected since the preliminary budget was not preserved or project reports did not have clear indications on activity duration.

This project had a planned duration of 13 months, 3070 work hours, and contained four distinctive milestones: Two formal reviews with the customer and two test campaigns with the Science Team.

An additional advantage is that this project will soon continue into its production stage (C/D-phase). Thus the effort spent on evaluating project evaluation in the conceptual stage (B-phase) can be used during the continued project if proven successful.

4.2.2 Sources of data

The following historical data will be assembled and used to compile the perceived project progress:

- Preliminary budget
- Project plan
- Project reports
- Financial data from the accounting system, and the resulting progress graphs

Were possible one data point / month is used.

4.2.2.1 Project data

The Project Plan is compiled by the Project Manager and Account Manager at project start and approved by the Department Manager. It contains start and end dates for the project as well as intended dates for the major milestones such as customer reviews. A brief description of the resources needed is also included.

Project Reports are compiled by the Project Manager monthly as an input to the monthly review by the project Steering Group. The report contains data on project progress and the progress graph (Actual Cost in relation to Planned Cost).
4.2.2.2 Financial data

The Preliminary Budget is compiled by the Project Manager and Account Manager at project start and approved by the Department Manager.

The three types of project costs are:

- Costs for man-hours delivered (Arbets Kostnad = AK). The cost debited to the project is formalised in three categories of hourly rates for different types of personnel, and is not directly related to the salaries of the individual. These hourly rates also include costs for company overhead and social benefits. The work-hours spent are reported related to work-package by each individual on a weekly basis.

- Direct cost (Direkta Kostnader = DK). This is the actual cost for materials and services purchased by the project. When consultants are employed as workforce during work-intense periods their wages are treated as Direct Cost. To be able to measure performance according to the original baseline the consultant costs must be transferred from Direct Cost to Man Hours.

- Laboratory Fee: This is a small amount debited per man-hour in work packages utilising laboratories and/or instruments. It is used to cover the costs for wear and renewing of instruments and facilities.

The raw data is stored in the company accounting system which is updated on a monthly basis. The system uses the Swedish Accounting Plan to distinguish the different types of cost. Both Work-Hours and Cost are retrievable from the system. These will be used as input to the revised project follow-up. One data point/month will be retrieved, correlated with the monthly project reports.

4.2.3 Tools

An improved version of the existing Excel sheet will be used to implement the comparison and to generate graphs for each consecutive month.

The original chart only contained means for plotting and visualising the data retrieved from the Accounting System. In order to implement the performance measuring it has now been extended with:

Preliminary Budget data: The data is extracted from the work-packages and each component assigned a cost in work-hours and Direct Cost. Thus the originally planned costs are preserved during the whole project.

Bar-graph diagram for work-package tracking: This graph visualises the cost development in the individual work-packages

Earned Value tracking: The Work-Package budgets from the Preliminary budget are used to track the actual work performed. A monthly check of which parts have been "delivered" is done at the same time as the Project Report is compiled.

Earned Value calculation: An additional sheet containing the calculations on the Earned Value and performance factors is added.
4.2.4 Performance factors

To be able to apply Earned Value Management on a project the measurement of the actual Earned Value is a critical point. The success of the method relies on the possibility to define reliable criteria on the deliveries.

Possible factors to assess Earned Value in P&R projects:

1) Number of man-hours delivered in each work-package, as compared to budgeted hours.
2) Work-package cost related to budget.
3) Milestones reached, and their timeliness
4) Completed work-packages
5) Completed tasks within work-packages

Discussion:

Work packages at P&R are organized after specialties; this means that for example the work package “Electronics” will contain activities that are executed during a major part of the projects duration. To be able to measure performance the Work Packages must be sub-divided in smaller blocks of activities with a limited duration (Sub-Activities). The Planned Work for each time unit will then consist of Sub-Activities from many Work Packages.

Some Work Packages are consistent over the whole project duration, for example “Management”. This means that the Sub-Activity may be best modelled as a number of work-hours, same for each time unit.

If problems appear in one specialty area this may be interesting to keep track of. If activities from all specialties are bundled together a problem area and a successful area may hide each other.

Depending on the skill of the resources allotted to a task, more hours may need to be spent, but the cost remain the same, or less hours may cost more.

There are different models to assess the completeness of a (sub)-activity:

- The activity earns its total value when completed
- The activity earns a part of its value when started and the rest when completed.
- The activity earns parts of its value when pre-defined milestones are reached

For simple tasks the first model is the easiest to apply. To minimise the amount of work needed to keep track of the project progress it is therefore beneficial to spend some time at start of the project to break down the planned work into smaller activities with limited duration. This is also beneficial for the budgeting, since parts of the work are often forgotten when assessing the time needed for more complex activities.

Problems:

Unforeseen work (caused by poorly defined activities) may not be possible to get into a Sub-Activity.

Poor quality may cause need to return to the same activity again.

Scope creep can increase costs without adding value to the original scope.
4.2.5 Application of the Earned Value method
The following steps were performed:

1) The project plan was used to define the intended duration and Budget At Completion (BAC) for the project and the duration.

2) Work Package Descriptions (WPD) were used to list all activities to be performed in the scope of the project, listed per work package.

3) The preliminary budget was used to find the cost/value for each activity.

4) Data from the monthly project reports were reviewed to find dates for completion of activities.

5) Activities were assigned an Earned Value on the following basis:
   - Completed activities: Assigned a value in the month they were reported as finished
   - Continuous activities (i.e. project management): Total value split equally over all months the project was intended to run, no value for extra months

6) The excel sheet used to track project budget performance status was extended to contain also the Earned Value, CPI, SPI, EAC and TCPI

4.2.6 Results
The following paragraph is a summary of the results and reflections gained when applying the Earned Value management method to the selected project. All graphs are compiled from the analysed data by the author.

4.2.6.1 Project baseline
From the Project Plan the following data can be extracted:

Baseline:

Project duration: 12 months
Budget At Competition: 3771
Milestones:

<table>
<thead>
<tr>
<th>Milestone Description</th>
<th>Schedule Date</th>
<th>Actual date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning meeting</td>
<td>January 2013</td>
<td>February 2013</td>
</tr>
<tr>
<td>Experiment Requirements Review</td>
<td>March 2013</td>
<td>February 2013</td>
</tr>
<tr>
<td>Breadboard 1 test campaign</td>
<td>April 2013</td>
<td>May 2013</td>
</tr>
<tr>
<td>Breadboard 2 test campaign</td>
<td>September 2013</td>
<td>November 2013</td>
</tr>
<tr>
<td>Design Analysis Meeting</td>
<td>October 2013</td>
<td>December 2013</td>
</tr>
<tr>
<td>Critical Design Review</td>
<td>December 2013</td>
<td>March 2014</td>
</tr>
</tbody>
</table>

The project was planned to run for 12 months, but did not finish on time. In the analysis the planned budget is divided over the planned 12 months. Actual Cost is plotted for 15 months, but the project goals were still not fully reached within this timeframe.
Baseline changes:

Extra work was added during the months June-July and September, but no changes to the baseline were made. Also manufacturing of materials intended for and delivered to another project was accounted for in this project. This amount was low, but caused a temporary excess of incomes over expenditure for one of the work-packages.

4.2.6.2 Planning and reporting of activities

The monthly description of activity status in the project reports was essential to enable an assessment of the Earned Value, combined with the insight gained from working in the project. Comparison to another project showed that it is very difficult to assess the duration of activities retrospectively without having a thorough knowledge of the project. It proved too hard to determine the point where activities were finally closed out. Although the activities/Tasks to be performed were defined in the WBS for both projects, the reporting did not clearly refer to these.

Also the description of activity content is very important; if the scope is loosely defined it is hard to ensure that the activity is completed.

Visual indicators to show the project managers (subjective) perception of project status was used in the reports:

<table>
<thead>
<tr>
<th>Technical results</th>
<th>Schedule</th>
<th>Cost</th>
<th>Risk</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green circle</td>
<td>Yellow triangle</td>
<td>Red diamond</td>
<td>Green circle</td>
<td>Yellow triangle</td>
</tr>
</tbody>
</table>

Figure: 4-5 Visual indicators used in project reports (SSC, Månadsrapport XRMON-SOL, 2014)

- Green circle - performance is OK
- Yellow triangle - performance is deviating, should be observed
- Red diamond - performance deviation that needs action to be taken

Compiled over the project duration the indicators change as follows:

<table>
<thead>
<tr>
<th>Month</th>
<th>Technical results</th>
<th>Schedule</th>
<th>Cost</th>
<th>Risk</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Green circle</td>
<td>Green circle</td>
<td>Green circle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>2</td>
<td>Green circle</td>
<td>Yellow triangle</td>
<td>Yellow triangle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>3</td>
<td>Green circle</td>
<td>Yellow triangle</td>
<td>Yellow triangle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>4</td>
<td>Green circle</td>
<td>Yellow triangle</td>
<td>Yellow triangle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>5</td>
<td>Green circle</td>
<td>Green circle</td>
<td>Green circle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>6</td>
<td>Green circle</td>
<td>Green circle</td>
<td>Green circle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>7</td>
<td>Green circle</td>
<td>Yellow triangle</td>
<td>Yellow triangle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>8</td>
<td>Green circle</td>
<td>Yellow triangle</td>
<td>Yellow triangle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>9</td>
<td>Green circle</td>
<td>Yellow triangle</td>
<td>Yellow triangle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>10</td>
<td>Green circle</td>
<td>Yellow triangle</td>
<td>Yellow triangle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>11</td>
<td>Green circle</td>
<td>Yellow triangle</td>
<td>Yellow triangle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
<tr>
<td>12</td>
<td>Green circle</td>
<td>Yellow triangle</td>
<td>Yellow triangle</td>
<td>Green circle</td>
<td>Green circle</td>
</tr>
</tbody>
</table>

Figure: 4-6 Summary of visual indication development in project reports during project (Author)
It can be seen that already in February is some problems with schedule and cost development perceived, but not until November is the severity realised.

4.2.6.3 **Earned Value**

A matrix was set up showing the planned activities as described in the preliminary budget and ticking them off at full value at the time they were completed. This was surprisingly easy to implement and worked well for most activities with two exceptions: Long duration activities and loosely defined activities.

![Figure 4-6: Earned Value matrix (part): Two activities within a work package contribute to total Earned Value](Author)

It is hard to assess progress in activities that have long duration. The fact that often the "last 10% will take 90% of the time to finalise" is well known. Therefore some effort should be spent on dividing activities with long duration into smaller parts so the progress, or lack of progress, can be detected.

Tasks that are loosely defined are also hard to measure, such as "Ensure compatibility between subsystems". A better definition may for example be "Review Interface Specification for compatibility between sub-systems".

The original plan was to only assign an Earned Value when the activity was completed, but this caused very diverse delivery results, with much value delivered at milestones and little between. A second run of the Earned Value assessment was then performed, assigning the value of long tasks as 20% at start and 80% at completion. This helped a little, but to be completely successful these tasks should be divided into smaller units.
Figure 4-7: Earned Value matrix (part): Activity contribution to total Earned Value using 20/80% model (Author)

Mapping of Earned Value to Planned Value and Actual Cost:

Figure 4-8: Project cost graph including Earned Value, first version (Author)
After application of the 20/80% division of long tasks the Earned Value curve gets a bit smoother:

![Project cost graph including Earned Value, improved version](image)

**Figure 4-9: Project cost graph including Earned Value, improved version (Author)**

It can be noted that since the completion of activities were extracted from the monthly project reports, a lag of up to one month may be seen in the curve for Earned Value. This may explain the gap between the curves at start, but not the fact that the gap widens during the project execution.
4.2.6.4 Schedule Variance and Cost Variance

The Schedule Variance ($SV_e$) is the difference between the Earned Value and the Planned Value ($SV_e = EV-PV$). It shows if the project is on time, expressed in an amount of cost that can be converted to working hours. (But for this purpose the Schedule Performance Index (SPI) is better used.) This curve can give an indication if activities are really completed continuously or only when really needed because a milestone is approaching.

In this graph the milestones for the two Breadboard campaigns and the preparations for the CDR can easily be detected. The fact that fewer activities were delivered than planned during September and October may be caused by many parallel tasks being executed or that tasks have not been divided into short enough activities, which was probably true for the test campaigns that including all specialities contained approximately 600 hours of work each.

The Cost Variance ($CV_e$) is the difference between the Earned Value at the reporting time and the amount of money spent (Actual Cost). This value expresses the actual “lag” in budget and can be an interesting factor to visualise. Here it is clear that something happens in October. The project is now preparing for the second Breadboard Test Campaign and at the same time extra, unplanned, work (weight reductions) is being performed, using additional resources. This causes a large “dip” in the cost variance which then stabilises again at a lower level until again extra resources are added in preparation of the Critical Review milestone.

Figure 4-10: Schedule variance $SV_e$ (Author)
The Schedule Performance indexes show the rate of the time plan execution. (see chapter 3.2.2.3) This is defined as $SPI_p = PV/EV$ ($SPI_e = EV/PV$ in American literature). The curves will then look as following for our project:

The monthly indexes clearly show the extended efforts before milestones, while the accumulative curve show a constant tendency of a speed of approx. 1.4 slower than the plan during most of the project duration.
The Cost Performance index shows the rate of the cost execution. This is defined as CPIp = AC/EV (CPIe= EV/AC in American literature). The curves will then look as following for our project:

![Cost performance index](image)

Figure 4-13: Cost performance index CPIp (Author)

Also here we see that all value is delivered at the milestones. The accumulated tendency is however a constant cost efficiency of approx. 60% (cost increase factor 1.65).
4.2.6.6 Bulls-eye diagram
An alternative way to display how the CPI\textsubscript{e} and SPI\textsubscript{e} factors develop over time a "Bulls Eye" diagram can be used. In this Diagram the project variance factors are plotted in an XY plot for each reporting point. The four fields will then represent:

- Over budget/Behind schedule
- Over budget/Before schedule
- Under budget/Behind schedule
- Under budget/Before schedule

If an allowed deviation is decided it can easily be seen at the monthly evaluation if/when the indexes go outside this.

![Figure 4-14: Bulls-eye diagram showing the project status at the reporting points (Author)](image-url)
4.2.6.7 **Estimate At Completion**

The Estimate At Completion can be calculated in three different ways, depending on which factors are important in the project. These are described in chapter 3.1.2.

![Figure 4-15: Estimate at Completed plotted for all three calculation possibilities (Author)](image)

4.2.6.8 **The Estimate At Completion (budgeted rate)**

This forecast is based only on the Budget At Completion and the Cost Variance: \( \text{EAC} = \text{AC} + \text{BAC} - \text{EV} = \text{BAC} - \text{CV} \).

As expected the trending show the same distinct 2-step characteristic as the CV, going from one rather stable level to another in October. This is reflected in the Project Report as the addition of extra resources to be able to deliver on time.
4.2.6.9  **The Estimate At Completion (cumulative SPI)**

(This is the same calculation as the “Final Cost” above)

Here the curve shows a deviating value in April. This is because very little Earned Value is assigned to the months March and April. A large delivery in May (Breadboard Test 1) turns the curve back to a “normal” level again. In this case a strategy using “% complete” with a higher percentage at activity start or “assigning a part of the Earned Value on activity start” would have levelled out the curve showing a more consistent behaviour over the project execution time. Dividing the activities in smaller sub-activities would also have improved the behaviour.
### 4.2.6.10 The Estimate At Completion SPI and CPI

The third version of estimate takes both CPI and SPI into consideration. In this way more information is used in the calculation, but for a small, short-duration, project with uneven deliveries this results in a very unstable prediction. Small deviations get amplified.

The low progress in April cause forecasts based on CPI to show extreme values. If Earned Value rules are changed so that activities longer than 40 hours are given 20% of the final value on start these extremes are filtered, without destroying the general information.

![Diagram](image.png)

*Figure 4-18: Estimate at completion SPI and CPI (Author)*

All three methods show a realistic and stable trend after about 35% of the project time, but the estimated level varies between the methods.

### 4.2.6.11 To Complete Performance Index

The To Complete Performance Index is used to give an idea on how much effort is needed to finalise the project on time.

The index is calculated as $\text{TCPI}_{bac} = \frac{(\text{BAC} - \text{EV}_{cum})}{(\text{BAC} - \text{AC}_{cum})}$ if the Budget at Completion is considered valid.

If it is clear that the BAC cannot be met a revised budget (EAC) shall be determined and used for the calculation: $\text{TCPI}_{bac} = \frac{(\text{BAC} - \text{EV}_{cum})}{(\text{EAC} - \text{AC}_{cum})}$

For this project it is clear already in September that the original budget cannot be met. At this time the Estimate At Complete using the three different methods indicate a final value of 4800, 5780 and 7930. A re-calculated budget estimate set to 6000 (original 3771) will then generate the following curve:
The trend continues and in February a new Estimate at Complete must be calculated. This time indicated by 6380, 6500 and 6590). A revised EAC of 6500 is set.

Figure 4-20: To complete performance index after second budget re-calculation (Author)
4.2.6.12 Using CPI and SPI to compile quick-look data

Antvik-Sjöholm (Philipson & Antvik, 2009) and (Antvik & Sjöholm, 2012) suggest using the performance perspective for SPI and CPI ($SPI_p$ and $CPI_p$). This is beneficial since these factors can be directly used to calculate a forecast for the final cost and time for finalisation.

The inverted value used to predict time and cost:

\[
\text{Total Duration} = \text{project Planned Time} \times SPI_p
\]

\[
\text{Final Cost} = \text{Budget At Completion} \times CPI_p
\]

The plotted data will look as follows:

![Figure 4-21: Total duration calculated from SPIp (green) and cumulative SPIp (red) (Author)](image1)

![Figure 4-22: Final cost calculated from CPIp (blue) and cumulative CPIp (red) (Author)](image2)

Despite the monthly variations the cumulative trends are stable from month 5 and onwards.
4.2.6.13 Using CPI\textsubscript{e} and TCPI to compile quick-look data

Fleming & Koppelman (Fleming & Koppelman, 2008) suggest instead using CPI\textsubscript{e} and TCPI as performance indicators. This will give the following graph:

![Graph showing project progress using CPI\textsubscript{e} and TCPI](image)

Figure 4-23: Project progress using CPI and TCPI (Author)

In October the Actual Cost for the project exceed the original Budget At Completion. Now a revised Estimate At Completion must be calculated. This can then be used to measure the To Complete Performance Index, TCPI, for the rest of the project. This method for compiling a quick-look data plot may be less intuitive than the total duration and total cost calculation in the previous diagram, but is also informative.

The fact that the project delivers only 60-70\% of the intended value is visible and stable. Consequently the effort needed to finalise on budget is constantly increasing.

4.2.7 Sources of uncertainty

When applying these indexes some analysis of the sources of uncertainties must be considered:

- Interdependencies of activities
- Not all work is described as activities (under-defined work-packages)
- Poorly defined activities where same work is assigned twice
- Latency in reporting
- Scope changes without re-planning
- Changes in resource allocation: Budget, schedule or change of personnel
- Activity planning: If activity duration is not planned in a correct way the Planned Value will differ from the Earned Value and the Actual Cost.
4.3 Other metrics and methods

4.3.1 Work-package Block diagrams

To compile a block diagram showing the cost development for each work-package and the budgeted cost is a relatively easy method to see the cost development for parts of the project. It will look as below:

![Figure 4-24: Work-package block diagram (Author)](image)

The diagram above show actual cost compared to planned cost per work-package. It can clearly be seen that some work-packages show overrun while other are below budget. The causes for this should be investigated. Overruns can be caused by problems during development, but also by scope-creep or by faulty reporting of costs. Poor reporting may be detected by unexpectedly low costs in other work-packages assigned to the same resources.
4.3.2 Milestone Trend Chart

The forecasted date for the milestone is displayed on the vertical axis and the revised dates logged along the horizontal axis for each update. In the graph below the schedule changes in the project can clearly be detected:

- April: Resource sharing with other projects
- September: Limited availability of customer
- November: Key team member has accident and is temporarily unavailable

![Milestone Trend Chart](image)

Figure 4-25: Milestone trend chart (Author)

The graph gives a clear indication that the delays seen early in the project could not be caught up, even if there was some hope during the project execution. Instead further delays were added, partly because of scope creep.
4.4 **Interviews on project evaluation**

If project evaluation shall become an asset for the organisation it is important that the project managers and project owners think that they will benefit from the input and are willing to perform the additional work needed. The perceived gain must be higher than the extra effort needed to learn and use a new tool.

In order to assess the perceived need for additional project evaluation and need for improvement three interviews were held, one interview with one person each from the three main stakeholder positions. The scope of these interviews is to clarify the stakeholder’s views of:

- The perceived need for project follow-up and forecasting during the project
- The workload of performing follow-up tasks
- Satisfaction with the current situation
- Need for improvement and willingness to adapt to new ideas

The interviewed stakeholders represent the following functions:

- Project/Resource Owner
- Main Project Manager
- Sub-Project Manager

Notes from the interviews are found in appendix 2. The questions and answers have been translated from Swedish to English.

### 4.4.1 Summary of findings from interviews

#### 4.4.1.1 Methods used

The methods used to keep track of the projects mentioned in the interviews were:

- Meetings with project team, weekly or as needed
- Monthly compilation of data from accounting system
- Monthly follow up against schedule
- Lists of action items

A general concern seems to be the detail of information. Here the demands differ between the sources. Some want detail, others need a summary.

The current monthly reports form a sort of a project logbook, but should at the same time not have a high level of detail to facilitate the reporting to the steering group. There is no specification of the level of information needed. Important issues need to be listed as "action items" not to be overlooked.

The time plan is important, but some problems exist because interdependencies between projects are not shown, and because persons assess the level of completion in different ways. This may cause tasks to be delayed because the resources were not available or did only schedule the actual design work, not the related tasks needed.

A number of different software packages are used to plan and follow up the project progress. These are not integrated and therefore data must be compiled manually and transferred between tools.
4.4.1.2 *Satisfaction with current evaluation methods*

The satisfaction with the budget performance analysis done by extracting the monthly cost for work performed and mapping it to the planned cost is good, in spite of the manual work needed. All interviewees expressed satisfaction with the visualisation of the cost as compared with the intended spending.

4.4.1.3 *The benefit of progress tracking*

The benefit seen is to know that the project is moving forward and to be able to communicate this to the customer. Knowledge if project progress is necessary to be able to solve problems early. The information collected is also used as input for quotations for future projects.

4.4.1.4 *Satisfaction with the available data*

The data available is good, but some data is not readily available. The largest problem is to get the team members to report the work-hours performed to the correct account. It is hard to correct this if done wrong.

4.4.1.5 *Alternative use of the available data*

Automated reporting of data from the accounting system and correlation to the time-planning system would be an improvement. In this way the progress tracking could be automated. But at the same time the manual checking of data validity would be lost.

Visual indicators could be good to give a quick overview of status. One factor that is not checked now is the number of people assigned to a project. This number is related to the project overhead, since also people working few hours need to participate in team meetings and similar.

Monthly visualisation of cost per work package could be good, and then a possible overrun could be detected early.

Converting cost for external resources to the work-hours used to track progress is complicated, but easier than it used to be.

4.4.1.6 *Need for additional data*

It is easier to assess the progress when a project has regular milestones. An agile-inspired way of working would introduce a sort of "milestones".

A more clear and up-to-date resource planning, showing project interdependencies, would enable the project managers to foresee resource related delays caused by project interdependencies.

4.4.1.7 *Willingness to spend effort on calculating forecasts*

No time for additional calculations exist. The need is unclear, if projects seem to be progressing on plan there is no need. But at the same time there are requests for forecasts from the management.

4.4.1.8 *Additional comments*

Costs stemming from platform changes not requested by the project should be handled at a central level since it is an unforeseen cost at project level.

Good teamwork in the projects is essential to achieve good results. Additional efforts to build teams effectively would improve the projects deliveries.
5 Discussion and analysis

In this chapter all the findings from the study are described and discussed. First the input to the study from the interviews is described. Then the data found in the project reports is evaluated and possibilities for improvement discussed. Finally the results from application of the method to the historical data are described. The 10-step model is used to assess the feasibility to implement Earned Value Management at P&R SSC and examples on how the implementation can be done are given, using the tools available for planning and scheduling. This part can also be used as a start for a future "implementation manual".

5.1 Interviews
The perceived need of the organisation for improvements in project performance analysis and forecasting was assessed through three interviews. The notes from these are found in appendix 2, and the outcome is summarised in chapter 4.4.

5.1.1 Will the Earned Value method be accepted by the project managers?
The perceived need for improvements in project performance analysis and forecasting as described in the interviews is relatively low. A general satisfaction with the current state was expressed, especially after the update of the Excel sheet that links the preliminary budget and the performance tracking. More automated data retrieval from the support systems would be helpful, but is not essential. Spending extra time in order to get a forecast was thought to be “nice to have”, but not considered to be needed as long as the project seemed to show good progress. This attitude is a bit problematic, since there will be little interest in investing the effort to learn and applying a new method for performance measurement if no need is seen for it. Then it is easier to just continue as is.

It is clear that in order to achieve better acceptance the method should be further investigated, by applying it to a ongoing project, so that the value of continuous performance tracking can be demonstrated. In this way the data from this project can be compared to the data from other, concurrent, projects and the advantages will become apparent.

5.1.2 Problems in implementing the method
The largest problem in the performance analysis is the mapping of performed work-hours to work packages. Here the project manager must be very active to see that costs are mapped to the correct account, and errors are difficult to correct. At the moment no way to improve this way of reporting exists. In the future the tool for reporting may be improved, making the process easier, but it will still be needed to be performed manually by each team member.

A more urgent problem affecting the project progress is the lack of up-to-date resource planning. Conflicts on resource availability were seen as the most common source of delays. Here the same planning procedures as needed for Earned Value may be valuable, since they can be used to compile a resource plan together with the time-schedule. Thus the extra effort needed to define tasks and activities in a way suitable for Earned Value assessment in the planning phase can be of dual use.

5.2 Project reports as a tool to describe progress and outcome
Over all the project reports contained valuable information on the project progress, but the form it is given in makes it difficult to digest for a person not well acquainted with the project specifics. This was clearly expressed in the interviews. Although a form is used to compile the reports, each project manager handles this in his/her own way. The request for detail in the reports also differs between the stakeholders.
One way to improve this is to use more visual indicators. In this way any person wanting to see the state of the project can get a first impression without having to read through and evaluating all the information. Visual indicators are widely used in industry, because it is easier to perceive information visually than in writing or by oral communication. This is a part of the Lean concept of reducing "waste" (Greif, 1991).

To improve visibility the reports can be re-organised to containing a brief summary of the project status and visual indicators in the beginning and more detailed information later/in a separate chapter. In this way an overview of the project status can be gained already at the first page of the report and only those wanting more thorough information on the current tasks and activities need to read further.

A revised report form, containing more visual indicators, and used in a more consistent way over the whole project portfolio would increase the value of the project reports, and also win more common acceptance.

Something that is not covered well in the project reports is the baseline and changes or updates to this. A way to preserve the baseline and clearly define which changes have been made during the project execution is needed. This could for example be comparison between original budget and revised budget, updated target dates compared to original plan and changes in other resources. The Project Plan is important as a description of the original baseline, although it does not describe the details. Therefore this information also needs to be stated in the project reports.

5.2.1 Information in the project reports
When performing this evaluation of a historical project the most important information in the report was:

- Performed actions since last report. These were used as input to the EVM analysis. In order to compress the report these could be moved to the Excel sheet instead, just leaving the main events in the report.
- Dates for achieved milestones and information on perceived delays, for example caused of resources not being available when needed. This information was used to compile the Milestone Trend Chart. The baseline for these dates were not set very firmly in the Project Plan and was not followed up in the same way by all authors. Here the system used in the reports from BIM-3 project was to be recommended.
- The financial information makes a good visual indication on the actual cost, but data has to be retrieved from the Excel sheet. It could be seen that the project baseline was not quite defined at project start, and also some adjustments to the calculations during the project changed the perceived progress.
- The assessment of delays in time schedule was rather good. More information on this was found in the text than in the schedule.
- The "traffic light" indicators for schedule, budget, resources etc. looked good, but did only show the project managers perception of the project status. In this way they were more influenced by the personality of the project manager than of what was actually delivered in the project. An advantage is that also the concept of quality (described in terms of Technical results and Risk) are covered, which are not addressed by Earned Value management.
5.2.2 Additional thoughts on the project report form

- The curves on budget performance are extracted from the Excel sheet. With addition of Earned Value these will be more valuable since the cost can be related to the actual delivery.
- Work-package bar-charts show a good indication if a specific work-package is experiencing problems and should be added to the report form.
- The time schedule does not add much information on a detailed level, and can be removed. When lag appears in the project it is often distributed over more than one activity, which makes the schedule a poor tool to visualise this. The Milestone Trend Chart may be a more valuable tool in order to gain a superficial knowledge of the progress as related to the baseline.

5.3 Results from applying EVM to historical data

5.3.1 Post-mortem application of Earned value

The application of the method proved more feasible than had been expected, mostly because the limited amount of activities and time-span. The earning rules had to be adapted for tasks that extended over a longer time: Here the 20/80% rule improved the earning value curve and removed some of the “wobbliness” seen in the first iteration using only 100% on delivery as earning rule.

Some activities were not formulated in a way that made the goal quite clear. For example external reviews often had a certain amount of post-meeting activities, decided on at the meeting but not foreseen or included in the activity scope. This resulted in the activity being ticked off as delivered, but work-hours were still consumed.

Some activities had a loose scope and had to be treated as ongoing work and split over the project duration. The same applied of course to project management which by nature is a continuous activity. The earning rule of dividing work over the planned months worked well for these activities since there were not too many activities of this type.

The baseline was not fully set and documented at project start. Also the budget limits for the project was re-defined and it was unclear if any managements reserve existed. This caused some variations on target values in the early versions of the project reports.

During the executions some additional activities were added to the project, but without adding more resources. This caused a scope creep. Some of these activities can be regarded as early execution of activities budgeted for in the next project phase. In this case a delta calculation on the added costs and impact on execution time should have been done. The best would have been to also add an extra work-package for the additional work. This had made it possible to assess its impact in an easy way.

5.3.2 Comparison of data between used graphs and revised graphs

The EV curve achieved showed good conformance with the actual project progress. It would have been a good indication of the actual performance during the project execution. The fact that the project performance in terms of time and budget consumption showed an efficiency of approx. 70% was not quite understood, and the fact that no solid data was at hand, just "gut feeling", made concerns for the project progress hard to communicate.

Forecast curves (Estimate At Completion, EAC) showed some extreme values at start, but from 4-5 months into the project the forecast was stable and close to the final results. This can certainly be used as a tool for forecasting performance in coming projects.
Addition of Work-package bar charts increased the visualisation of status in the respective work-packages which made it easier to find the cause of overruns.

The Milestone Trend diagram made a good visualisation on schedule slippages and could well be used for future projects.

5.3.3 Comparison of project managers assessment of project situation as described in project reports to the image received by EVM analysis
When reading the project reports it is obvious that the project situation is understood by the project manager, but no real data on the situation is at hand. This made it hard to gain acceptance on management level. If figures on schedule slippage and cost overrun had been at hand corrective actions may have been possible.

5.4 Does the available data fulfil the needs for an analysis of the progress?
The available data is sufficient to perform analysis of budget spent in relation to planned value, which is already being done. The data can also be used for other types of analysis, such as mapping of work-package cost evolution over time. To be able to implement Earned Value analysis some extra efforts are needed in the planning phase, so that activities can be "delivered" to the project, see below.

5.5 Feasibility of practical implementation of the EVM method
The following requirements are necessary to be able to implement EVM at P&R following the 10-step model defined at FMV (Antvik & Sjöholm, 2012) and (Antvik, 1999):

5.5.1 The project goals
A clear baseline is needed and should be documented in the Project Plan:

- Definition of scope
- Time schedule with start and stop dates and milestones
- Project budget

The requirements for reporting and performance tracking should be clear from start, since it is hard to add these later on. Preferably a template for project reporting shall be ready and its usage communicated at project kick-off. In this way a consistent reporting for all sub-projects can be achieved. Fixed dates shall be set for milestones, and synchronised on all project levels.

The “GAO Cost Estimating and Assessment Guide,” chapter 18, (GAO, 2009), recommends to perform an “Integrated Baseline Review” that checks that all the elements defining the project limits are at place. Parts of this checklist could be integrated in the P&R management system.
5.5.2 The WBS

All work must be organised into work packages. This is already done and works well. The same structure used in all projects, which enables a post-mortem comparison between projects.

Figure 5-1: Work break-down structure (SSC)

The Work Package Descriptions (WPD’s) needs to be improved: The WPD’s contain all tasks/activities to be carried out in the work-package. These descriptions must be complete and all the contained activities well defined and of short duration. All activities must be budgeted and have a clear criteria for finalisation. All work must be described, so that no work outside budget will have to be performed. Here some additional effort must be made compared to the current state.

5.5.3 Organisational structure

A person responsible for the project performance tracking should be appointed and the reporting process to management/steering group be decided at project start.

Resources and personnel should be appointed to fulfil all specialities needed, and a plan for staffing any missing specialities done at an early stage.

An improved analysis of resource utilisation during the project execution is needed, to enable cross-project resource management. Now the input to the resource planning tool is too weak, and not correlated to the Schedule and Planned Value curve. It is not easy to implement this in the Excel sheet since all data must be retrieved from other sources.
5.5.4 Responsibilities
Responsibilities are formally assigned down to sub-project level. Within the sub-projects the responsibility assignment is informal, but since the teams have few members most tasks are assigned according to the members different specialities. The same team member may be active in more than one speciality, when needed.

<table>
<thead>
<tr>
<th>Pre &amp; Post Campaign</th>
<th>PM</th>
<th>Sys Eng</th>
<th>SW Eng</th>
<th>El Eng</th>
<th>Mek Eng</th>
<th>PA/QA</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Preparation and packing of modules, GSE, tools and spare</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5-2: Example of time planning over specialities (SSC)

It is essential that all project members have enough understanding of the tasks assigned to them, so they can account for the work performed in a correct way. This can be achieved by distributing the work-package descriptions to all members in the project team and revisiting them regularly. Changes in staffing will require additional efforts in this respect.

Figure 5-3: Responsibility allocation (SCC)
5.5.5 Time Schedule

For the XRMON-SOL B-phase a classic Gantt planning was used, see below. This plan showed the intended duration of the main project activities, but it was hard to see the progress.

![Gantt planning with milestones from XRMON-SOL project B-phase (SSC)](image)

To improve the performance measurement the time schedule should be organized in a way such that tasks can be completed at a steady pace. Longer sub-activities should be split in parts with shorter time duration. This enables the assessment of Earned Value to be performed by an easy method - all value earned at completion.

An "agile-inspired" work model may improve this: Work can be organised in shorter "sprints" or time-boxes of 2-4 weeks duration. Longer tasks are then split into parts matching the time boxes, so that the completion can be checked each month (Knightech, Seminar 2014-02-18). This is also beneficial in the way that the work-load for each month is more easily visualised.
The time-boxes are then organised in longer duration activities, in the same way as the original plan.

Dependencies between activities are also possible to include in this model, but it is probably better to keep track of these in another way. In small projects dependencies are often rather obvious.
5.5.6 Preliminary Budget

The preliminary budget is the most essential part of the project planning since it serves as the cornerstone for the quotation to the customer, the tool for planning resource allocation and the measuring unit for project progress. The preliminary budget should be done well before submitting the quotation to the customer and preserved during the whole project. All changes and updates should be carefully recorded and any changes in scope that may impose additional costs be discussed with the steering group and the customer.

Figure 5-7: Preliminary budget (SSC)

To assure a good prediction of the project cost the preliminary budget should be based on the work packages. Each work package description must be broken down in sub-activities with a limited duration, preferably of maximum 4 weeks.

Splitting the planned work-hours on the different specialities involved in the tasks is beneficial, not only to make a correct assessment of the workload for the task, but also enables an automatic resource plan to be output, if the Excel sheet is linked to the planning tool in the future.

5.5.7 Actual Costs

The Actual Costs must be manually extracted from the accounting system.

Figure 5-8: Actual Costs (SSC)

It would be very beneficial if the project managers could get this data automatically each month in the form of an automatically generated report, in Excel format. This would save the effort of performing a tedious manual task. This would also serve as a reminder that it is time to compile the monthly project report.

The cost for externally purchased services (consultants) must be converted to work-hours since this is the planning unit used in the preliminary budget. It is therefore important that all bills contain the actual amount of work-hours spent on different tasks. Replacing staff with consultants will of course generate a difference in cost per work-hour. This will have an impact on the Actual Cost, but not very large as long as the work-hours remain at the planned amount.
5.5.8 Deliveries

Each activity defined in the Work Packages and in the Preliminary Budget should have a limited duration and criteria for reaching "finished" state. It may not be marked as complete until this criteria has been met, otherwise a heap of residual activity may build up at the end of the project.

Milestones should be defined in the projects. These shall also contain the work to be done in preparation and finalisation of the milestone such as preparing presentations before and compiling minutes and action lists after meetings. Each milestone is regarded as a sub-activity.

Dates for meetings are also useful as an indication of schedule performance, for example in a Milestone Trend Chart. In this case the actual date for the meeting can be used.

5.5.9 Earned Value

Since projects are small the "100% at completion" rule makes large impacts on the Earned Value tracking. Therefore it should only be used on shorter duration tasks <2 weeks. For longer tasks the rule 20% at activity start, 80% at completion should be applied, otherwise the EV-curve will lag and the performance indexes show a very unstable profile.

The Earned Value should be measured by:

- 100% completed for shorter duration tasks
- 20% at start / 80% at completion for longer duration tasks (such as Integration Tests)
- Monthly hours for continuous tasks (Management)
- "Passed" status for milestones (Reviews)
Implementation in Excel:

<table>
<thead>
<tr>
<th>Earned Value</th>
<th>Total</th>
<th>Finished</th>
<th>Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meetings &amp; Reviews</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5-10: Follow-up of Earned Value (Author)

The Earned Value is ticked off monthly in the Excel sheet, using the same task break-down as used in the preliminary budget.

5.5.10 Analysis of actual situation

The monthly Project Report is the project manager’s tool for checking and summarising the project status. It is also used by the main project manager to report to the Steering Group. This report should contain:

- A short summary of the project progress intended for the management/steering group
- Data on milestone fulfilment as related to baseline dates
- The curves for Planned Value, Actual Cost and Earned Value.
- A forecast of the project performance, using SPI and CPI to express the possible deviations from the planned budget and schedule.
- Block diagrams showing Work Hours and Direct Cost spent on each work package in relation to plan.
- Summary of the resource situation
- A list of completed tasks

The same information should be presented to the project team at project meetings, so that the team can decide how to resolve delays and overruns together.

A project report template using EVM graphs to visualise the project status is found in appendix 3.

5.6 Additional information received by applying the EVM method

If the Earned Value method is applied on the projects at P&R a forecast of the project cost and timeliness can be achieved. This information is not available today. However, to have relevance the validity of this information must be ensured, and the calculated data accepted by management. If the results are not understood, or the validity not trusted, no new knowledge is gained.
6 Conclusions and recommendations

In this chapter the outcome of the study is summarised. Based on this some recommendations on improvements and future enhancements are given. It also contains some ideas on topics for further study.

6.1 Summary of the analysis

The main question to be answered by this work was formulated as:

How can the Earned Value Management method be applied for the projects run at P&R SSC?

To help answer this also some corollary questions were formulated:

1. Do the stakeholders (management, project managers and steering group) see need for improvements in project follow-up and forecasting?
2. Would an improved forecasting of project performance improve the possibility to finish projects timely, i.e. by adding more resources?
3. Can the suggested method be implemented in such a way that its application does not cost much more manpower to maintain?
4. Will the additional effort of understanding and applying a new method find acceptance by the project managers and the department managers?
5. Does the available data fulfil the needs for an analysis of the project progress or must more or different data be collected?
6. Can the same data be used to show other project metrics that is of interest?
7. Can early warnings on schedule and/or budget slippage be detected when applying historical data?

The questions have been answered as follows:

1) **Maybe.** Improvements in project follow-up and forecasting are welcomed by some, but others do not see any need and express satisfaction with current situation. The need is more expressed in the terms of being able to report accurately to the accounting functions. Some concern for the additional workload is seen. Since the response is neither positive nor negative a pilot application may be needed to visualise the benefits of the method.
2) **Yes.** The analysis shows clearly that more tasks were delivered when additional man-power was added to the project team. In this way the project can be finished earlier, but at a higher cost.
3) **Yes.** It has been shown that if some consideration is taken during the project planning phase it is relatively easy to implement the Earned Value method. The additional work-load to formulate tasks/activities in a way so that they can be easily "delivered", and adding this to the excel sheet used for follow-up, can be assessed to 1-2 work-days. During execution approximately 1-3 hours/month for ticking off completed activities may be needed.
4) **Maybe.** The limited time available for project and department managers can be an obstacle in implementing the method. But since the attitudes are open to new methods a successful pilot application can be valuable. The 10-step feasibility study in chapter 5.5 can be used to compile an implementation manual to aid this.
5) **Yes.** All data needed can be compiled from the support systems, with some effort. Some small improvements in the planning phase are needed as mentioned above.
6) **Yes.** The data compiled for Earned Value measurement can also be used to compile improved time-schedules and, with some effort, to compile resource plans. The need for resource plans is seen as high in the interviews. This possibility may therefore be an advantageous bonus when implementation the Earned Value method.

7) **Yes.** Cost and schedule performance indexes showed early in the project that the baseline would not be fulfilled. They provided a more accurate assessment of the situation than the project manager’s perception.

The following factors are seen as important for the implementation:

- All data needed to implement Earned Value Management are available at P&R SSC.
- Since the projects are small and have limited number of activities the implementation of the method is not difficult, if only the planning stage is well performed.
- The project planning process need to be revised in order to have activities and "earning rules" matching the method.
- The data gained from applying the method is shown to provide an early warning for latencies and cost deviations.
- The general attitude towards project performance tracking is satisfaction with the current state. In a situation where time is in short supply there is low interest in spending additional time to adapt a previously untested method that no demand exist for. According to interviews this effort may be better spent on improving the resource planning routines at the present time. New demands from management can however increase the willingness to adapt to new ideas on this topic.
- The fact that up to six different software packages is needed to perform the continuous tasks on planning and managing the projects is not seen as a problem, probably since all interviewees are used to do this. Integrating several of these tasks in one tool could however save a lot of time, protect the validity of the data better, and decrease the learning curve for staff new to the task. It may also improve the consistency of the reporting between projects.

The conclusion from the above answers is that the main question can be answered with "**Yes**". It is possible to implement Earned Value Management for the projects run at P&R, but a pilot implementation may be needed in order to win acceptance.
6.2 Conclusion
As summarised above all data needed to perform Earned Value Analysis are possible to extract from the company support systems, with some effort. The project process fulfils the 10-step model, but can be improved, especially in the reporting from the accounting system and the planning of activities. The Excel sheet used can easily be extended to also contain Earned Value and additional metrics, but is sensitive to mistakes that may compromise the relatively un-protected calculations.

The project managers have the knowledge to perform the tasks needed to apply Earned Value management, but if this shall be done in a consistent way an agreement on how it should be done must be made, for example by compiling an "implementation manual" similar to chapter 5.5 above and adding this to the Management System. A pilot implementation on a "sharp" project should be made to demonstrate the value of the method during project execution and thus win increased acceptance from the management.

Additional methods are found that may be used to further improve the step 10 "analysis of the actual situation", without adding a severely increased work-load. The data collected can be used to improve other parts of the project management process, such as time-schedule compilation and resource planning.

6.3 Recommendations
It is the author's firm opinion that applying Earned Value Management would mean an improvement on project performance tracking at P&R. In order to demonstrate this, the method should be applied on at least one project. In this way experience on improvements needed in the project planning process can be gained, and the validity of the results be verified.

In implementing Earned Value Management an increased focus will be put on establishing a fixed baseline, deliverables and finalisation of activities. Even if the method will eventually not be used for all projects, this mind-set will prove beneficial to the project execution.

Usage of graphs and other visual indicators in the reporting of project status to management and steering groups should be extended. In this way an understanding of the project situation could be gained without in-depth knowledge of the project specifics. This is especially important on management level where time is limited. In this way time could be spent on preventing and solving conflicts instead of understanding project details.

In the short term the Excel sheet should be extended to also handle resource utilisation, and correlate it to the time schedule so that more accurate data can be transferred to the department resource planning tool. This will improve the over-all resource planning between projects.

Excel is a versatile tool, but it is also easy to by accident affect the data matrices in an unwanted way. To protect data it would be good to at least write a software application that protects the database and implements the calculations for the trend data. This software may also interface to the project planning tool which has an API (Application Programming Interface - a possibility to interface the tool to access data). For the future a more versatile tool integrating most of the used features is needed. Compiling a specification for this and performing a market survey to find possible tools may be a good topic for a future thesis student.
To become truly successful the decision to use Earned Value Management must be taken on management level, and an education effort be made so that all the project managers have a common vision on how and why the method should be applied. The employees that have worked on the pilot project can later be used as a reference group, and "competence centre".

6.4 Topics for further study
Except for the need for a more versatile tool mentioned above the following topics are possible for further study:

**Resource allocation:** By implementing the Earned Value method all activities in the project are defined. When these are divided on disciplines as done in the preliminary budget and then coupled to the time schedule as described above all input needed to compile a resource plan is at hand. An automated compilation of resource plans, serving as input to the department planning in Silberplan could become a great asset.

**Automated reports:** It would probably not be very hard to implement automatic reports from the accounting system. It would however need cooperation with the accounting department and a short duration employment of a consultant. This issue must be handled on department/division level.

**Visual indicators:** It is always easier to assess the state of things using visual indicators instead of raw data. By implementing the Earned Value curve, block diagrams for work-package development and milestone diagrams this has been improved. A further improvement of the visual indicators and linking them to a status panel on the intranet team-site would provide even better visibility.

**Critical path analysis:** This method could be useful to visualise the task interdependencies in projects. Some support for this already exists in the project planning tools. It is however a larger step to implement this, and it should therefore be done as a separate study. Since the project progress is heavily linked to resource availability, for both personnel and hardware, and some form of critical path analysis including these factors would be useful.
Afterword

There has been a long journey ending in this thesis. Starting just for fun with a single course on Project Planning at KTH in the autumn of 2005, and continuing while working full time on my ordinary job, until now in the summer of 2014 with this thesis. To become a student again after more than 25 years’ work experience means that I have a very different point of view compared to my early student days when I was a full time student; work experience will let you assimilate the material in different way since it can be related to real needs in the working environment.

The opportunity to return to the school bench and the luxury of getting new and interesting ideas presented to you, and also the opportunity to meet and discuss with both teachers and fellow students, has been a very rewarding experience. I will therefore take the opportunity to thank some of the people that have made this time an experience that will always remain a good memory for me:

Sven Antvik, who was both my project management teacher and the tutor for this work. Sven's well-structured classes rendered project management procedure easy to understand, and management theories a topic that was fun to discuss. The input gained from Sven's vast knowledge on applying Earned Value Management theory in real projects (from FMV) has been a good fundament to build on when exploring our comparatively small-scale projects.

Also the importance of celebrating achieved project goals was well illustrated by Sven’s initiative to treat all your students to the traditional "Gustav Adolf celebration" cake when the whole course passed the written examination. This will remain a very good memory for all of us, and especially for the foreign students.

My colleagues at P&R SSC who provided all the materials and inputs to this thesis, willingly volunteered to be interviewed and contributed many good suggestions and ideas for improvements in the project planning and control process.

Peter Rathsman who took the time to hold a very interesting presentation on the experiences gained in the SMART-1 project to a group of unknown students. Peter managed to transmit a lot of "real-life" knowledge on project management to us during his presentation and he also contributed some valuable insights on how to best handle the customer.

Roland Langhé who gave us all a first insight in project planning and the importance of having the PMBOK on your desk. The Sweden Rally assignment Roland designed for our first course, complete with a real-life display of the historical cars to run the race, definitely set the level and added some extra flavor to the program!

Mi Wretlind who managed to plan all my courses during the nine years.

All fellow students of different nationalities and ages. It was fun to work together! And even if the schedule was short and the work was hard at times we always succeeded in delivering our assignments and presentations in the end. Thank you for the good cooperation!

Stockholm 15 September 2014

Ylva Houltz
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### Abbreviations

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<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>EV</td>
<td>Earned Value</td>
</tr>
<tr>
<td>EVM</td>
<td>Earned Value Management</td>
</tr>
<tr>
<td>AC</td>
<td>Actual Cost</td>
</tr>
<tr>
<td>PV</td>
<td>Planned Value</td>
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<td>CPI</td>
<td>Cost Performance Index</td>
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<tr>
<td>SPI</td>
<td>Schedule Performance Index</td>
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<td>CV</td>
<td>Cost Variance</td>
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<tr>
<td>BAC</td>
<td>Budget At Completion</td>
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<tr>
<td>EAC</td>
<td>Estimate At Completion</td>
</tr>
<tr>
<td>SV</td>
<td>Schedule Variance</td>
</tr>
<tr>
<td>TCPI</td>
<td>To-Complete Performance Index</td>
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<tr>
<td>BCWS</td>
<td>Budgeted Cost for Work Scheduled</td>
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<tr>
<td>ACWP</td>
<td>Actual Cost for Work Performed</td>
</tr>
<tr>
<td>BCWP</td>
<td>Budgeted Cost for Work Performed</td>
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Appendices

1. Interview questions
2. Notes from interviews
   - Notes from interview 1
   - Notes from interview 2
   - Notes from interview 3
Appendix 1: Interview questions

Hur gör du för att följa upp dina projekt?

*Which methods are you currently using to keep track of you project(s)?*

Är du nöjd med den uppföljning av projekten som görs nu?

*Are you satisfied with the existing project evaluation?*

Vad är syftet med att följa upp våra projekt?

*What is the intended benefit of following up on project progress?*

Tycker du att du får värdefull information från den analys som görs nu?

*Is the data gathered and analysed now giving you useful information?*

Skulle man kunna använda den tillgängliga informationen på något ytterligare sätt?

*Could the gathered information be used in other ways?*

Finns det någon information du saknar i dagens läge?

*Is there any information that you feel is missing in the current state?*

Skulle du tycka det var värt besväret att lägga någon timma extra varje månad för att få en bättre prognos på om projektet kan förväntas sluta i tid och på budget?

*Would you judge it worthwhile to spend some additional time every month if that meant that you could get a more accurate prognosis on the final cost and timeliness of the project?*

Hur skulle du använda en sådan information om den fanns?

*If you had that information, how would you use it?*

Har du några andra idéer angående detta som du vill dela med dig av?

*Do you have any other ideas on this subject that you would like to share?*
Appendix 2: Notes from interviews

Notes from interview 1: Sub-project manager

*Which methods are you currently using to keep track of your project(s)?*

That depends on the status of the project. Some of the things I do is:

- Weekly meetings with the project team
- If everything is on plan weekly meetings can be replaced by talking to the team members one at a time
- Monthly compilation of project data from the accounting system
- Monthly follow up of activities against time schedule, especially to check that no activities block for adjacent activities.

Further comments:

- The main thing to look for are activities that take longer than estimated and activities that can block the following activities. Under-estimations can be difficult to handle if found at a late point in the project.

- Some specialists tend to only estimate the time it takes to complete the actual task, and do not allow for the corollary activities like documentation. It is important to know this. It is a great help to have worked together with the team member/sub-contractor before, then it is easier to know if the person is prone to over or underestimating.

- It is important that the team members get an accurate knowledge of what is to be achieved in the project. It is important that the project manager can give the picture so that good enough quality is delivered, but no over-engineering takes place.

- It is not necessary to keep track of activities that are not critical for the timeline. It might not make any difference if they are late.

- It is important that the project manager has a realistic view of the project status. He/she should neither "be in the blue" nor dig too deep into details.

*Are you satisfied with the existing project evaluation?*

*For your own project level (sub-project)?*

- Since my project is a re-flight of a previously flown experiment I have good knowledge of the work to be performed. I am also very satisfied with our new sub-contractor. We have not worked with this company before, and even if they have worked with space projects before this has been on a larger scale, so the way of working with this type of projects is new for them. It is very important to build up a personal relation with the sub-contractor so that an
open dialogue can be maintained.

**On main project level?**

In total I think we have good control of the project status.

We have some problems in following up our goals. The project limitations with regards to the customer are a bit floating and the project is delayed.

The communication and planning across projects is poor. New project utilising the same resources may appear suddenly, causing delays. It is hard to assess the impact on ones own project when key resources are employed in other projects too, and the amount of available time is not clearly stated.

**What is the intended benefit of following up on project progress?**

It is good to have a clear picture of the project status, and to know that nothing has been overlooked. It is not constructive to overdo the task of following up the project. It should be related to the project status; if there is a calm period there is no need to follow up as frequently as when there is a lot of activity going on.

It is important to remember the lessons learned for coming projects. In my previous project we had a key resource reassigned to a more urgent project, this caused my project to come to a standstill where no one could come forward until the pending work was preformed. If that would happen again I would be prepared to either close the project until internal resources are available, or take in an external resource to keep the project progress up.

**Is the data gathered and analysed now giving you useful information?**

I think the available information is valuable and good. There is not any specific information that I feel is missing. The effort of extracting the information from the accounting system is easily performed. You get used to the interface.

The dream would be that the accounting system could be connected to the time-planning system so that data could be correlated directly and progress be plotted to performance directly.

**Could the gathered information be used in other ways?**

Time purchased from consultants is not logged in a good way. We plan our projects on man-hours and we get the cost for consultants as a Direct Cost. This means that you need to convert this to man-hours by manually go looking for the bills and contracts to find the cost and hours delivered. It is also unclear if the laboratory fee is added to this or not.

There is no need to separate internal resources on different hourly costs when planning the project cost. Most employees have the same hourly rate and the differences between the different levels are too small to make a large impact on the total project cost.
A good thing would be to visualise the cost for each work-package per month compared to the planned cost. Then an overrun or delay may be detected early.

It is important to give feedback to team members when time is debited to the wrong work package so that it can be debited on the correct account. Otherwise the final analysis at project end will not be correct.

**Is there any information that you feel is missing in the current state?**

The resource planning is unclear and often not available. Therefore it is hard for the project managers to see if their resources are planned on parallel activities and when.

**Would you judge it worthwhile to spend some additional time every month if that meant that you could get a more accurate prognosis on the final cost and timeliness of the project?**

That depends on what the problem is. Change of key personnel leading to a different working pace is hard to foresee. A lot of things make impact on the project progress: Change of personnel, availability, new tasks being added.

Agile methods do not work in our environment. It is too hard to measure pace when you work with new and previously untested tasks and technologies.

**If you had that information, how would you use it?**

I doubt that it would be worthwhile the effort to perform more analysis, because of the nature of our tasks.

**Do you have any other ideas on this subject that you would like to share?**

Too much time is spent on discussion about technology changes on system level, and by changes inflicted by the customer. This time should be accounted for separately since it is an unforeseen cost in the sub-projects. It is more of a department level problem and should be handled there. More focus should be put on good enough performance and the actual cost of doing things. There is no use spending 100 hours work to save the value of 50 hours.
Notes from interview 2: Main project manager

Which methods are you currently using to keep track of your project(s)?

I mainly get my information from the project meetings that I hold, and from the monthly status reports my sub-system project managers compile. At the meetings the sub-project managers report the progress in the sub-projects and we discuss the status. I do not have time for “management by walking around” so it is better to get all reports at the same time. I used to have a deeper knowledge of the project specifics, but there is no time for that anymore. It is even hard to get enough time between the project meetings to handle the information gained.

I also maintain an action item list on system level and check that at the meetings that no important topics are overlooked.

It is difficult to get the project reports delivered in time and the level of detail differs a lot. It can be difficult to distinguish the important parts. I report in my turn to the Steering Group by submitting a report and participating in a monthly follow-up meeting. It is equally hard to keep this report at a good level so that it does not contain too much detail, but detailed enough to serve as a sort of “project logbook”.

The time schedule is an important tool to see that the project is on track. One thing that can delay the project is unforeseen interference from other projects that compete for the same resources. The reason is that we are a small department and cannot deploy persons to just one project. It is easier to keep the schedule when the department only has one project at a time and everyone works in that same project.

A way to improve this could be to have an administrative project assistant that can follow up on action items. It would be more effective than having the engineers asking each other all the time.

Are you satisfied with the existing project evaluation?

The monthly budget performance evaluation is a good tool. The improved version of the Excel sheet works well.

Having a project room where all project information could be stored and displayed would be an asset.

Using power-point to visualize the work packages, tasks and problems for the project team at project meetings would give them a better overview of the project outside their own specialty and enhance the quality of the reporting.

It is hard to see why things sometimes are not performed as planned, and whether it is a temporary disturbance or a system level problem. I do not like when problems are just stated in the project reports. I want them to contain a suggested solution too.
On sub-project level?

The budget follow-up is good, but the only prognosis is the amount that we assess and add in the diagram. This is based on the project managers assessment of remaining time and work performed.

On main project level?

The situation has changed on company level and the budget performance reporting has become more extensive. It is a bit hard to understand the effect of our hourly rates in a general perspective; If more hours than expected are produced during the month we generate a “deficit”, but at the same time most of the staff gets no additional payment for working overtime. In total you have to be able to assess the results early on, so the financial department can assess the monthly cost and the cash flow.

What is the intended benefit of following up on project progress?

You cannot know that the goals will be reached without following up on the project progress. A lot of things are dependent on the individual performer, and no matter in what way, you have to solve your problems somehow. The communication with the project owner is essential since we only have projects with external financing. In other parts of our department, projects can sometimes be performed with internal financing and this is a totally different situation that does not necessarily call for a lot of following up activities.

Is the data gathered and analysed now providing you with useful information?

We recently had a workshop on the reporting from the accounting system. It is obvious that the needs for information are very different in different parts and functions of the company, like cash flow and foreign currency transactions. From my point of view it has become harder to get access to some of the data I need, such as incoming payments. The fact that the economy department have a different interface to the system does not improve their understanding of our needs. Data that is easily accessible for them may be inaccessible for us.

I think it is good to compile the monthly results manually since that gives you a check of the validity of data. You can more easily spot things that have been reported to the wrong account. But if you could get the data as a graph too, that would of course also be good.

One thing that could be improved is the time reporting system which output quite useless data now. I get one post for each person/ day and project and must add them up manually if I want to use the data.

Sometimes team members report worked time on the wrong project/work package, which is cumbersome to correct, I cannot do that myself but must ask the accounting department to change that. But it is important to get this right in order to see where the work-hours were spent.

Changes to the scope of work should always be tracked. For larger changes we charge the
customer immediately, but for smaller changes we sum them up in a basket that is processed from time to time. Even if our business is of a volatile nature it is important not to accept changes that one does not understand the reason for, and not to carry out changes for free.

**Could the gathered information be used in other ways?**

It would be a help if the preliminary budget and the current situation could be compared directly as a report from the accounting system.

The resource planning could be improved. It is hard to see which resources are available. The team members are not aware of the planning and can sometimes continue working on projects that are closed. The planning is not updated frequently and is not always adhered to by the sub-project managers and team members, partly because it is not available to them. If we had a project room the resource plan is something that could well be posted on the wall for everyone to see!

Using indicators to give a visual indication of the status without having to read details could be good. We have already started using that, but it can be improved.

The fact that the accounting system now let you see the invoices for consultants mean that their work can be tracked as work hours, and it should always be done. It is important to let the consultant companies know that they shall report hours on project.

**Is there any information that you feel is missing in the current state?**

Sometimes we have long parts of the projects without discernible milestones. Then it is hard to see if the project is really moving forward at the intended pace. If there are milestones like breadboard test campaigns you get much more visible deliverables. It could be good to apply “Agile inspired” ideas where you check what has been delivered since last report.

**Would you judge it worthwhile to spend some additional time every month if that meant that you could get a more accurate prognosis on the final cost and timeliness of the project?**

We do not have time to spend on calculating prognoses, since that would generate more overhead. But at the same time everyone wants and requests them.

**If you had that information, how would you use it?**

Then we could re-shuffle resources in the projects early on if one sub-project seems to be heading into trouble. It is also possible to de-scope and avoid doing things better than “good enough”.

**Do you have any other ideas on this subject that you would like to share?**

The organisation of the project teams is important. Since there are so few team members the interpersonal relations mean a lot.
New employees need to be educated so they understand our way of working.

Job and room rotation could be a good tool to get people to work in new ways and constellations.

More team activities in the projects in order to improve the teamwork.
Notes from interview 3: Project owner

Which methods are you currently using to keep track of your project(s)?

I use six different softwares to keep track of the project related topics: Silber Plan to plan the personnel resources, Agresso to extract cost and work-hour data from the accounting system, HRM for the time reporting, Hansoft for the project planning, one Excel sheet for preliminary budget and follow-up for each project and one Excel sheet for over-all cost and income calculation.

Are you satisfied with the existing project evaluation?

It is not easy to get consistent data across the different softwares we use. You need to have in-depth knowledge of all projects to be able to assess the validity of data when updating. This causes an obstacle since there are few persons available that have enough overview to be able to do this. Those who have the overview are often fully occupied with other tasks so there is difficult to delegate these tasks.

When the workload is high, as it often is, we minimise the time we spend on updating the tools and do just the most necessary updated. Since we have long experience on working in this environment we can make a rough assessment “in our heads” that is good enough for assessment of the situation in a short perspective. It would be better to be able to update more frequently and this would also give a better idea of the situation in a long perspective.

It is very important that worked hours are allocated to the correct project accounts. If additional time is needed due to having to perform unforeseen tasks it is easy to open a new account so this additional effort can be captured. We should inform our project managers on this possibility.

What is the intended benefit of following up on project progress?

Learning: to provide input to the next tender

Early warning: so that we can take action early if problems arise

To see if projects will affect each other

To keep the project managers on track, and be able to provide feed-back on good things and help to solve problems on an early stage

We normally use the same similar organisation of activities into work-packages for all projects. This makes it possible to go back to previous projects and use the data from them both as input to the preliminary budget for new projects and to find the reason if we see problems in an on-going project.

Is the data gathered and analysed now giving you useful information?

We learn by reflecting on the results that we get, and especially when we analyse tasks that did not run as we expected. The project reports are a tool to see exactly how far the progresses in the projects have come, and the project meetings, if you can find time to participate. The project managers report in different ways, so it can sometimes be hard to really assess if the actual progress differs between them. We use the reports to get an indication if there are any problems that need to be addressed, i.e. missing resources.
The budget progress curve is good. The angle of this normally gives a good indication on the future progress in the project.

**Could the gathered information be used in other ways?**

It would be good to know the percentage of available work-hours that are actually available for the projects. Since we have many projects and the same people work in more than one at the time and also on business tasks such as marketing and preparation of quotations this would be beneficial to assess the overall situation at the department.

**Is there any information that you feel is missing in the current state?**

The time-reporting system is not well linked with the accounting system and not linked to the resource-planning system at all. This makes it hard to get a good picture of the available work-hours on the individual level since time spent on other activities then the project work cannot be assessed and therefore not be fed back to the resource planning.

The time schedule cannot easily be extracted from the planning tool for usage i.e. in reports. Therefore there is no good information on the time schedule in the project reports. There are no good ways to establish a baseline in the planning tool that can be used if we need to re-schedule. Also there is no good way to assess the number of work-hours between to milestones, so if one milestone is delayed we cannot see how much this will delay the next one. Since this is not linked to the preliminary budget we do not go back and re-calculate manually but make an assessment instead.

Would you judge it worthwhile to spend some additional time every month if that meant that you could get a more accurate prognosis on the final cost and timeliness of the project?

Yes, the request for progress data in order to follow up budget on department level has become higher. We have had some problem with this since our reporting has given uneven “wobbling” results in the last months so we need to improve on this part. This is especially important when working on ESA contracts since we get most parts of the payments after delivery.

**If you had that information, how would you use it?**

To improve the reporting back to our division controller, and to identify problems early in the projects so we can handle them in a proactive manner such as re/descope or add additional resources to overcome obstacles.

**Do you have any other ideas on this subject that you would like to share?**

We could improve the handling of management reserves in the projects. These exist in some sense now, but are not visible. Handling them differently would mean an easier way to see if the final result is within scope.

We can be clearer on the project limitations in execution time. If the launch is moved forward it will mean additional cost for the project and this should be taken into consideration already when compiling the quotation.
Appendix 3: Project report template using EVM graphs
1 Summary

Last report issued: 2014-00-00
This report contains data until: 2014-00-00
Next report expected: 2014-00-00

1.1 Activities

Brief description of project status "Executive summary"

1.2 Indicators

Green = on plan, yellow = not on plan, but moderate deviations, red = deviation that must be handled

2 Project activity report

2.1 Completed or on-going activities

• Activity on-going or completed during report period

2.2 Coming activities within next period

• Activities on-going or to be started during next report period

2.3 Sub-contractor activities

• Activities reported by sub-contractors

2.4 Resources

Personnel

Summary of personnel availability and requirements for next period

Other resources

Summary of resource availability and requirements for next period (localities, special tools etc.)

2.5 Other things to be noted

Any other data to be noted or information needed by stakeholders.
3 Budget and schedule status

3.1 Baseline

Note if baseline is preserved since project start (scope, schedule/duration, budget), or (significant) changes have been made. Analysis of consequences.

<table>
<thead>
<tr>
<th>Date</th>
<th>Scope</th>
<th>Schedule</th>
<th>Total Duration</th>
<th>Budget</th>
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<tr>
<td>2014-00-00</td>
<td>As defined in Quotation</td>
<td>First version</td>
<td>As defined in Quotation</td>
<td>As defined in Quotation</td>
</tr>
<tr>
<td>2014-00-00</td>
<td>Test session added</td>
<td>Updated</td>
<td>1 week extension</td>
<td>SEK xxx added to WP xxx</td>
</tr>
</tbody>
</table>

Description of changes.

3.2 Budget

Summary of current status for Earned Value and Actual Cost in relation to plan.
3.3 Schedule

Milestones

Comment on milestone completion

Main level Gantt chart

Comment on Gantt chart fulfilment
3.4 Work package status

Comment on cost development in work packages
4 Analysis and forecasting

4.1 Estimates on Cost development

Comment on development of CPI_p

Comment on EAC

Final cost at present performance: ..........
4.2 Estimates of Duration

Comment on SPI development

Total duration at present performance: .......... Months. End date: .........................

5 Quality

5.1 Technical status
Note any new inputs on technical status such as results from tests or breadboarding. Can requirements be fulfilled?

5.2 Risk status
Summary of status for identified risks in risk registry. Possible new risks identified.

5.3 Non-conformances and requirement deviations
List non-conformances or deviations from requirements, if detected.

5.4 Customer satisfaction
Note inputs and reactions from customer.