CHAPTER 1 INTRODUCTION AND PURPOSE OF THE STUDY

1.1 Introduction

In recent years, industrial plant maintenance has changed dramatically and these changes are due to a great increase in the number, variety and complexity of physical assets which must be maintained. Plant maintenance has been influenced significantly by innovations in plant instrumentation, computer and mechanical equipment as well as complex designs, new maintenance techniques and changing views on how to effectively conduct plant maintenance (Moubray 2003:1-2).

The process of plant maintenance has changed as a result of these changing expectations. This may be ascribed to a rapidly increasing awareness of the extent to which equipment failure affects safety and the environment. This increased awareness is also influenced by the relationship between maintenance, product quality and environmental issues. Industry is additionally under pressure to achieve higher plant availability and to maintain constant operating costs (Moubray 2003:2-3).

Process plant employees are limited in their ability to accurately and consistently monitor the health condition of various types of plant assets. Maintenance staff in large industrial plants is constrained by multiple databases and weak record keeping, and subsequently have little defence against aging equipment and asset failures (Honeywell 2003). Plant staff may devote up to 50 percent of their time reacting to asset failure issues (ARC White Paper 2003); sometimes very serious. Companies are beginning to implement planned equipment maintenance schedules; meaning installing new technology to allow for efficient tracking and analysing of equipment health across the board. The introduction of integrated asset monitoring solutions can enable maintenance staff to cost-effectively predict the potential of asset failure prior to occurrence of any actual plant incidents (ARC White Paper 2003:2).

A question that frequently arises in the operation of a plant include: Is the right **amount** of maintenance being conducted or is the right **type** of maintenance being conducted. These questions can be difficult to answer. Numerous preventative maintenance programs have been developed in recent the years (SAMI 2002) for a variety of reasons. At present there is not a single program in existence that is capable of taking care of all plant assets on its own. Stand alone systems that are currently available make it very difficult to be used in these maintenance programs (Joubert 2005) because they need dedicated attention and additional resources to operate and maintain.

The question therefore arises with regard to what aspects make it so difficult to conduct proper preventative or predictive maintenance on various plant assets?

Elements of preventative maintenance are well known (Mobley 1990). Certain tasks must be performed at a certain frequency and need to be scheduled and performed by qualified artisans or operators. Problems typically arise when an attempt is made to implement some sort of prevention in a reactive environment. A reactive environment often requires that unanticipated work must be performed and effective planning is required so that spare parts and equipment are readily available. One of the main concerns is the identification of the correct tasks and the appropriate frequencies at which these tasks must be performed.

Reliability Centred Maintenance (RCM) is often the tool of choice for plants sufficiently advanced to understand that preventative tasks must be aimed at correcting specific defects or failure causes (Moubray 2003:1-2). Insufficient resources unfortunately often result in the failure to correct specific defects and failures. In addition, the use of RCM techniques on every item of equipment is extremely time consuming.

This thesis documents an interpretative study undertaken to gain insight into the potential implementation of integrating different plant control and asset management systems into a single system. This would enable plant managers to effectively determine problems with regard to plant assets and subsequently establish a maintenance strategy that can maximise plant uptime.

This chapter provides an introduction to the concept of plant maintenance and presents an overview of the research that was conducted. The problem statements are presented in this chapter, the limitations of the study are discussed and the boundaries of the research are defined. The value of the research in terms of its contribution to industry is motivated. An overview of the chapters that follow is also presented in this chapter.

1.2 Objective of the study

1.2.1 Background

Prominent companies such as Sasol, Shell, Trans Alta, Union Camp, Mobil Oil Corporation, British Petroleum, Columbian Chemicals, Iron Ore Company of Canada and Montel have selected the Strategic Asset Management Inc (hereafter referred to as the SAMI model), for predictive plant maintenance. The SAMI model aims to improve production equipment health, employ the creativity of plant personnel in order to produce an improved skilled workforce, higher equipment utilization, lower maintenance costs and improved profits (SAMI 2002).

The Strategic Asset Management Inc. (SAMI) Company uses the Operational Reliability Maturity Continuum model (Figure 1) to assist the improvement of profitability, efficiency and equipment reliability for industrial organizations. The widespread use of the SAMI model by leading companies, as mentioned above, may be ascribed to the improved reliability that results from application of the SAMI model. Reliability may be used as a measure of a system's performance. If a system performs at 100 percent reliability, then the system functions at optimal levels that produce maximum outputs.

Should a system perform at any level lower than maximum reliability, the system may be considered to be inefficient and perform under optimal capacity.

The objective of plant maintenance is to assure the likelihood (probability) that equipment is capable to perform a certain function when required (SAMI 2002). Reactive maintenance can only minimise or reduce the impact of an equipment failure.

A reduction in the frequency of a failure mode leads to an increase in the probability of performing the intended task or function. Although all of the properties of components may be understood, there will remain uncertainty with regard to the timing of a given failure mode. The goal of plant maintenance is therefore to manage the probability of the performance of the intended function of the equipment (SAMI 2002).

As the assured availability of a plant approaches 100 percent, cost for maintenance escalates exponentially. The following question therefore arises:
"What is the appropriate type and amount of maintenance necessary to assure a specific level of performance for a specific asset?"

1.2.2 The SAMI model

The SAMI empirical model describes five different stages of mastery that form the foundation of improved performance and asset management (SAMI 2002). Once a proper maintenance process has been implemented, the plant's performance is likely to improve over time as proactive maintenance approaches are adopted in a staged and measured environment. The above-mentioned stages are represented in the SAMI Asset Healthcare Triangle as shown in Figure 1 below.

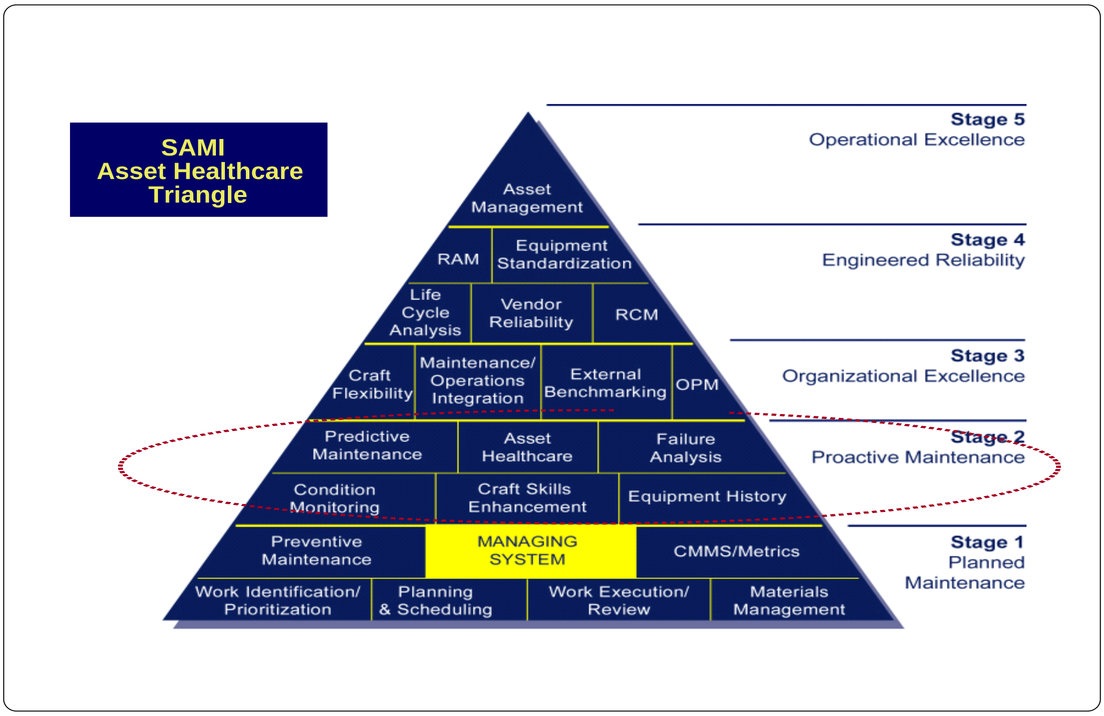

Figure 1: Operational reliability maturity continuum model

The stages of the SAMI model are summarised below:

Stage 1: Planned Maintenance. Focus is on planning and scheduling, work identification and prioritization, work execution, and moving towards preventative maintenance. This is managed by a management system such as SAP. This level represents reactive and preventative maintenance (SAMI 2002).

Stage 2: Proactive Maintenance. The proactive maintenance stage builds on the success of stage 1 (planned maintenance). RCM techniques are used to redesign the preventative and predictive maintenance systems to begin the reduction of failure events. Failure analysis and equipment history are used to eliminate failure modes (SAMI 2002).

Stage 3: Organizational Excellence. The organisational excellence stage explores resources outside maintenance and engineering to improve reliability. The focus is on human resources (operators and maintenance staff) who are involved in the maintenance process (SAMI 2002).

Stage 4: Engineered Reliability. The focus of the engineered reliability phase is on proactive elimination of failure modes and maintenance prevention. The impact of equipment failures is minimized and resources are used to identify equipment problems and to maintain proper health conditions of equipment (SAMI 2002).

Stage 5: Operational Excellence. The fifth stage of the SAMI Model is highly dependent on the reliability of equipment. A holistic approach is followed for asset management which integrates the cycle of annual business planning with equipment conditions in order to meet business requirements. The critical nature of equipment for all systems is evaluated, the correct current condition of equipment is monitored, and a zero-based maintenance strategy is developed for each component in the plant (SAMI 2002).

The second stage of the SAMI model, namely proactive maintenance will be considered in this study, in particular the development and implementation of an integrated solution to link all the blocks in the stage. Each of blocks can be viewed as problem areas that must be solved to allow for proper proactive maintenance. The blocks are briefly discussed below to clarify understanding of the asset healthcare model and the particular problems that are associated with pro-active maintenance (SAMI 2002).

- **Failure Analysis** – Data obtained from the symptoms of equipment failure must be used to establish and pre-empt the causes of failures. Analysis of the failure is must be undertaken be means of Root Cause Analysis (RCA) and Failure Modes and Effects Analysis (FMEA). Failure analysis may be considered from a hypothetical perspective by means of historical data regarding failure modes. In Stage 2, established failure modes are considered. A modified Failure Modes and Effects Analysis must be followed.
- A modified FMEA analysis allows maintenance staff to determine trends in terms of groups of related failures on equipment and consider multiple causes (Blaney 2006).

- **Asset Healthcare** – The asset effectiveness solution must provide for assets to maintain good health from a holistic perspective. Maintenance personnel can effectively target and manage plant assets that have the greatest impact on business success. The system must help personnel to become effective and efficient, optimizing operation and reducing costs (Honeywell 2004:1).

- **Equipment History** - The data pertaining to the previous performance of equipment and failure history must be obtained in order to guide the analysis and support proactive maintenance. In a SAP environment, the asset database must include failure catalogue information and work order histories including causes and functional locations. Data regarding the assets obtained from the database will allow cost and causal information to be pinpointed to related symptoms.

- **Failure Analysis** - The equipment that performs the worst is usually associated with varied factors regarding material, design, training, documentation, process, and material problems that add up to a unstable plant environment that is unable to cope with equipment faults (Blaney 2006). The information leading to a failure must be recorded so that the re-occurrence of symptoms preceding failure can be identified and acted upon in order to prevent equipment failure. The solution that is proposed in this thesis allows plant personnel to identify and act upon data obtained from field devices in order to maximise plant production and minimise loss through failure.

- **Skills Enhancement** – Training of maintenance personnel to understand the data obtained from field devices remains essential. Due to the open architecture of the solution, implementation of an integrated software interface must be accompanied by appropriate training so that maintenance personnel can competently interpret and react to data obtained from advanced field equipment. Modern plants contain diverse assets, from a wide variety of manufacturers that use industry standard communication protocols such as the Foundation Field bus, HART, Profibus and OLE for process control (OPC) (Honeywell 2004:1).

As the Asset Strategies get more sophisticated, maintenance personnel need to obtain additional training to make use of technological advances and diverse software platforms. Human resources that are equipped to cope with effective pro-active plant maintenance are required (Joubert 2005). Lack of training and experience in maintenance personnel can result in plant failures that could have been avoided.

The effect of poor training is evident in the case of the Secunda Refining Plant. Despite a month of clear vibration analysis output that predicted impending bearing failure, the production and maintenance leaders failed to read the data correctly and the subsequent plant failure and fire resulted in considerable losses. According to Blaney (2006), despite a sound asset management strategy, personnel at the specific plant did not know how to read and use the data obtained from the field devices and therefore did not react to information that predicted the failure. Employees were unable to read and understand the vibration reports on a pump; subsequently the equipment caught fire resulting in tremendous loss. Blaney (2006) ascribes the losses due to human error as a result of insufficient training.

- **Predictive Maintenance** - Maintenance plans and tools that use data other than measured time or running time to predict the condition of equipment and drive a maintenance schedule for it. Predictive tasks entail checking whether equipment is about to fail or has started failing. Predicting when failure is likely to occur is the aspect of maintenance that is considered to be proactive (Moubry 2003:7).

1.3 Problem statement

The problem statement is contained in the following question:

How can the various **blocks** in the second stage of the SAMI model be effectively used to develop an integrated solution to interface with diverse system platforms so that a proactive maintenance strategy in context of the Sasol Solvents environment is achieved?

1.4 Aim of the study

The aim of this study is to develop software interfaces connected to the different systems such as a plant distribution control systems (DCS), emergency shutdown systems (ESD), a loop management system, hardware management system, network management system and asset management systems and integrating them into a single system solution where all the plant assets status information can be monitored and viewed. The solution with its various plant control and asset management systems has not been developed or implemented previously referencing to the SAMI model.

The developed integration solution will enable maintenance managers to manage plant assets within proactive maintenance strategies to ensure maximum plant uptime and availability. The needs are defined for every block in the second stage of the SAMI model.

The objective of this research project was to develop a failure analysis model based on the newly developed symptoms and fault model that can be used for all plant assets. The model will be used to configure the symptoms and faults of all plant assets using the developed software interface. The single software interface makes use of configuration tools so that diverse interfaces can communicate to a central software interface called the **AlertManager** within the Honeywell based **AssetMax** software application.

- One of the specific goals of this research was to develop software interfaces to communicate with different plant control systems and field devices and to retrieve diagnostic information from these systems so that the status and availability of all plant assets can be monitored. In order to achieve the above-mentioned research objective, this thesis documents the development and configuration of an integrated solution capable of storing and retrieving information pertaining to diverse plant assets and using history information about failures in Root Cause Failure Analysis (RCFA) processes.

- To develop and configure an interface to access maintenance procedures, user manuals, data sheets and relevant process information to enhance the technical skills of the maintenance and process personnel.

- To use the results from the developed interfaces in maintenance strategies to ensure maximum asset availability and plant uptime.

1.5 Research methodology

1.5.1 Literature study

A comprehensive literature study was conducted with specific focus on asset management systems at various plants, nationally and abroad, the different vendors supplying these systems and the way they use these systems in proactive maintenance strategies. The study was conducted by consulting the internet, journals and internal documentation from several hardware and software suppliers.

1.5.2 Action research

Action research methodologies were used to facilitate the process of design and implementation of the different interfaces. This thesis documents the testing of these interfaces. The diagnostic information reports are interpreted and feedback is provided in order to change problem areas within the different interfaces.

1.5.3 Interface development

- Failure analysis model for all plant assets using the symptoms and fault model and the configuration of the models.
- Retrieval of diagnostic information from plant control systems and field devices to monitor their status and availability.
- To develop and configure an interface Management Information System to retrieve history from the different configured plant assets and using the data in Root Cause Failure Analysis (RCFA) processes and to determine the effectiveness of the maintenance strategies being used.
- To develop and configure an interface to have access to maintenance procedures, user manuals, data sheets and relevant process information to enhance the technical skills of the maintenance personnel.
- To use the results from the mentioned interfaces and use them in different type of maintenance strategies to ensure maximum asset availability and plant uptime.

1.5.4 Global developed integrated solution

The global developed integrated solution will be discussed in the thesis. This will include the described interfaces interfaced into one solution (AlertManager) where all the plant assets status information will be monitored and viewed. Sources used for the research include books referring to reliability centered maintenance, asset management and control systems. Articles looked at smart field equipment, asset management strategies and asset management solutions implemented. Research and conference papers were used for reference to smart field equipment used in asset management systems and the internet to look at the action research methodologies and field equipment being used in modern plants.

1.6 Contribution of the study

1.6.1 Integrated plant systems solution

This thesis presents an integrated plant systems solution and the research, development and implementation of the suggested integration between the different plant-based systems. The integrated system bridges the knowledge gap between plant operations and maintenance staff. The block diagram depicts how information can be relayed from plant systems to the maintenance personnel. The maintenance staff can utilize the information to improve the reliability and availability of plant assets (Honeywell, 2004).

The integration of the different plant systems that are used in the specific Sasol production plants is shown in Figure 2. The AlertManager interface (presented in the main red block) that is part of the Asset Manager Software (Honeywell 2004) will be used as the main asset management interface to view the information from the different interfaced systems to assist in the maintenance process as discussed in the SAMI model.

The reason for using the specific asset management software from Honeywell was a decision made by Sasol Technology management.

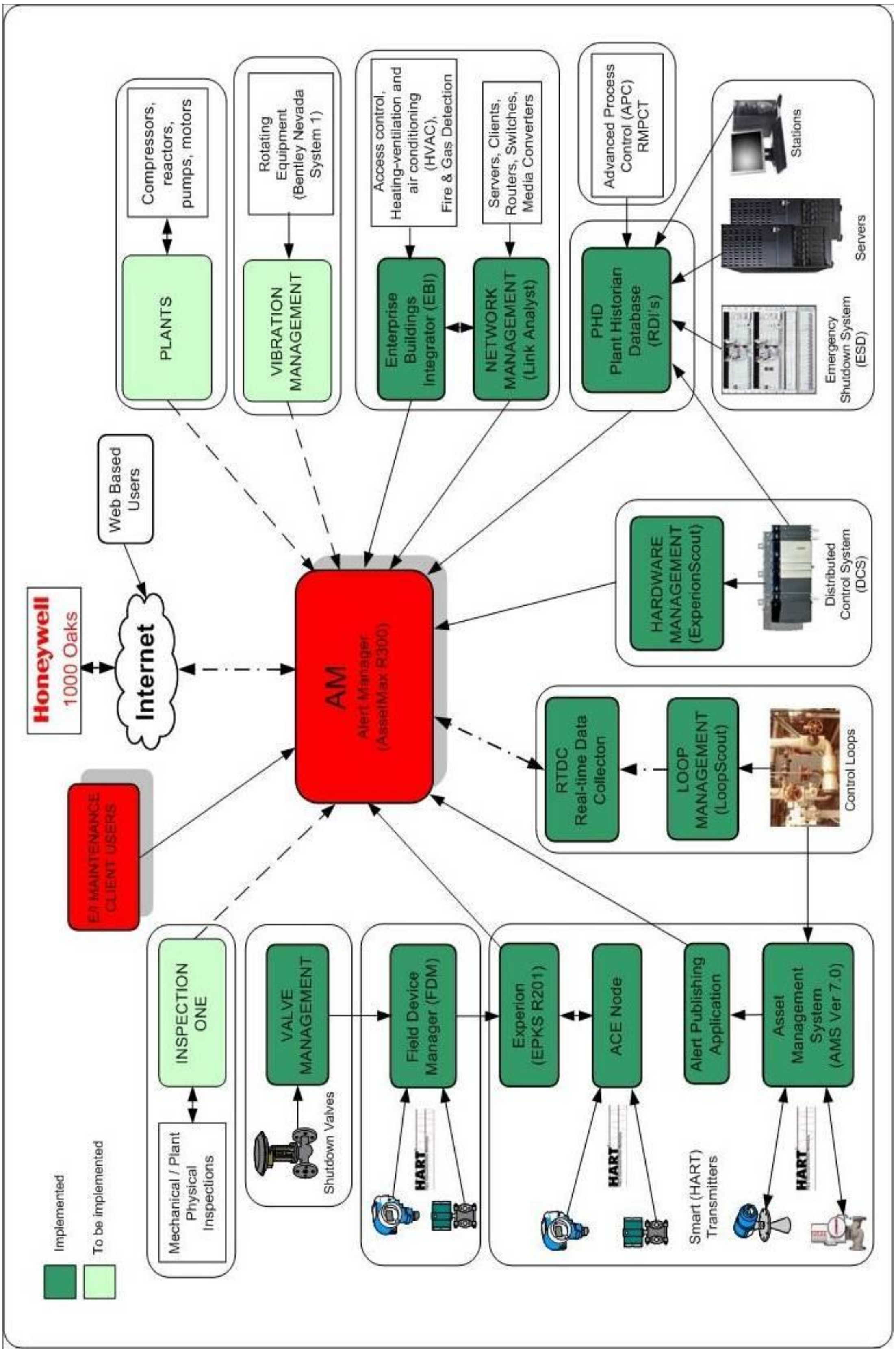

Figure 2: Block diagram of the different integrated plant systems

The HART-based intelligent field device monitoring systems (Joubert 2005) such as Emerson's AMS 6.2 (Emerson 2005a) and Field Device Manager (FDM) applications (on the left of the diagram) will be interfaced to the AlertManager (Honeywell 2006a). The control loop management system used to optimize loop performance, the distributed control system (DCS) and DCS hardware, the Fail Safe Control (FSC) system that is used as the Emergency Shutdown System (ESD) and ESD hardware will all be interfaced to the AlertManager (Joubert 2006).

The network management system (on the right of the diagram) which monitors the network and network components will be interfaced to the main AlertManager interface. The Enterprise Buildings Integrator (EBI) system that monitors the plant emergency evacuation system (PEAP) and components will also be interfaced to the main AlertManager interface. The Uniformance Plant Historian Database (PHD) will allow the different software interfaces to link to the AlertManager, all contributing to getting the data from the hardware devices that don't have normal software interfacing capabilities (Joubert 2005).

1.6.2 Contributions of this research project

- A total integrated solution is developed and implemented to assist maintenance personnel to move from a reactive (run-to-failure) maintenance strategy to a proactive maintenance strategy.
- Integration techniques used in this context may assist other companies by means of the introduction of new technology in their current plant asset management systems.
- The new system will save costs by preventing plant failure using the asset optimization solution.
- Improved valve management can be conducted by using valve signatures in a predictive maintenance strategy.
- The asset effective solution (implemented at the Sasol Chemical plant in Sasolburg) was submitted to the HART Communication Foundation and was

awarded the 2005 HART Plant of the Year award. Fifty five companies participated in the international competition (Hogan 2005).

- Two international and three national papers were generated as a direct result (consequence) of the work.
- The publishing of three articles in an accredited journal (submitted) also resulted from the work.
- The publishing of more articles in international journals.

1.7 Limitations

The vibration management system, namely the Bentley Nevada System 1, the mechanical plant inspections system “Inspection One” which is used for mechanical centric-based assets as well as the process monitoring system referred to as “plants” in figure 2 are planned for future integration and are not addressed in this research.

1.8 Term clarification

Active Asset	An asset is considered to be in an “Active” state when either a symptom or fault is present (i.e., the state is anything other than “Normal”)
Asset	Any subject entry into the Alert Manager. (i.e., Compressor, Pump, Control Valve, etc.)
Asset Folders	Information folders within the Asset Folder module used to gather data from specific plant assets, which the user needs for problem analysis and action
CMMS	Computerized Maintenance Management System
Evaluation Activity	An activity used to obtain the current status of a symptom that is important to the isolation of a possible fault
Fault	The malfunctioning of an asset. A fault may be associated with one or more symptoms

Fault Close Out	A fault is closed out when the operator determines that the fault has been repaired
Fault Elimination	When a fault is eliminated, it is no longer a candidate fault. This can be determined automatically by the absence of a required symptom or by operator knowledge
Normal Asset	An asset that is functioning properly (i.e., no symptoms or faults present)
Notification Activity	An activity (such as paging or email) that notifies personnel when a given symptom or fault is present, or absent
PID	Proportional, integral and derivative control
SCADA	SCADA refers to a system that collects data from various sensors at a factory, plant or in other remote locations and then sends this data to a central computer which then manages and controls the data
SIL	Safety integrity level refers to the impact it has on process equipment, human life and environmental hazards
SOAP	Simple Object Access Protocol
Symptom	Observable characteristics of an asset that may result in the malfunctioning (fault) of that asset. Relationships may be created within the Diagnostic Builder to trigger the recognition of faults
Symptom Details Activity	An activity that provides additional information about a given symptom
XML	Extensible Markup Language

1.9 Chapter layout

The research and conclusions of this study are discussed and summarised in the following chapters:

Chapter 1: Introduction and purpose of the study
Chapter 2: Literature Study
Chapter 3: Research Methodology and Design
Chapter 4: Failure Analysis
Chapter 5: Asset Healthcare
Chapter 6: Equipment History
Chapter 7: Skills Enhancement
Chapter 8: Predictive Maintenance
Chapter 9: Conclusions and recommendations