Quality Assurance in the Aerospace Industry: Implementation of AS 9100 Quality Management Standard at an SME

by
Corli Leonard

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Supervisor: Mr. Nico Treurnicht
Faculty of Engineering
Department of Industrial Engineering

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Declaration

By submitting this thesis/dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: 02/03/2011.....

Abstract

South Africa has potential to grow extensively as a country supplying components to the global aerospace industry supply chains, as well as directly to OEMs like Airbus, Boeing and Cessna which are first tier suppliers. The economic crisis had a significant impact on the growth of small to medium sized enterprises (SMEs), also in aerospace companies. Before the recession, SMEs did not see the necessity to become certified with internationally accredited quality standards, because there were an abundance of business opportunities. In the current restricted business climate SMEs are increasingly realising the importance of certification.

The standard that aerospace companies need to comply with, is the AS 9100 standard. Compliance to AS 9100 was previously considered as a competitive advantage (order winner) but has become a necessary prerequisite (order qualifier) to be considered for a contract.

In the aerospace industry accountability, traceability, documentation and quality of parts are of critical importance. Quality of products according to specification is crucial as it has a profound effect on safety. The tendency in improving of a company's processes is to scale down on superfluous documentation. In the case of aerospace companies, this is an extremely challenging goal because traceability is of such crucial importance in this sector in terms of aircraft structural system and –operational integrity.

For the purpose of this study, a small to medium manufacturer of aircraft and defence system parts was studied and considered to be representative of the aerospace industry in South Africa. The research gap amongst SMEs was investigated by means of a case study at an SME in South Africa where an IT-based AS 9100 quality management system was designed, developed and implemented. The investigation includes the analysis of the research partner's quality documents, the steps in the design and development of the quality management system (QMS) and a description of the implementation thereof.

This study aims to provide the focus group (SMEs) with more knowledge when developing their quality management systems for implementation of the AS 9100 requirement to compete in the aerospace industry. It describes the historic background and current use of the AS 9100 standard as background.

The objective of the case study will be to determine the generic validity of the method to be able to implement AS 9100 at a small to medium sized aerospace supplier when using the same guidelines which are followed in this specific case.

The method's value and success are determined by means of an external audit (certification audit) of the company used in the case study. The method makes specific use of an IT-based infrastructure to facilitate the reduction of unnecessary documentation. Experiences gained by the author in applying AS 9100 to upgrade local manufacturing companies to aerospace suppliers to Volvo Aero Company in Sweden are briefly discussed as well as the validity to make use of these generic steps.

Opsomming

Suid-Afrika het die potensiaal om betekenisvol te groei as ’n land wat komponente lewer aan internasionale lugvaart verskaffersnetwerke. Die ekonomiese krisis het 'n beduidende impak op die groei van klein tot mediumgrootte ondernemings gehad, asook in die lugvaart-industrie. Voor die resessie, het hierdie ondernemings nie die noodsaaklikheid om akkreditasie tot internasionale kwaliteitstandaarde te verkry na waarde geag nie, weens die genoegsame beskikbaarheid van sakegeleenthede. In die huidige ekonomiese klimaat word die belangrikheid van akkreditasie egter toenemend besef.

Die standaard waaraan maatskappye in die lugvaartindustrie moet voldoen is die AS 9100 kwaliteitsbeheerstelsel. Voorheen is die akkreditasie tot hierdie standaard gesien as ’n mededingende voordeel wanneer daar getender is vir ’n kontrak. Deesdae word dit as ’n noodsaaklike voorvereiste beskou, voordat die besigheid se aansoek om ’n kontrak te verkry eers oorweeg sal word.

In die lugvaartnywerheid is aanspreeklikheid, naspeurbaarheid en dokumentasie van kardinale belang. Die tendens in die verbetering van 'n maatskappy se prosesse is om af te skaal ten opsigte van onnodige dokumentasie. In die geval van lug- en ruimtevaartmaatskappye, is dit 'n uiters uitdagende doel, omdat naspeurbaarheid gedurende die komponent se leeftyd van deurslaggewende belang is in hierdie sektor.

Vir die doel van hierdie studie is 'n klein- tot mediumgrootte vervaardiger van lugvaartkomponente wat dien as navorsingsvennoot, bestudeer. Hulle is beskou as verteenwoordigend van die lugvaartnywerheid in Suid-Afrika vir die doel van die studie. Die navorsingsgaping is geïdentifiseer as die implementering van ’n gehaltebeheer stelsel wat voldoen aan die AS 9100 kwaliteitsbeheer standaard. Die gevallestudie van hierdie lugvaartvervaardiger sluit die bestudering van die ontwerp, ontwikkeling en implementering van ’n IT-gebaseerde AS 9100 gehaltestelsel in. In die studie word die navorsingsvennoot se kwaliteitstelsel en dokumente ontleed, en die stappe in die ontwerp en ontwikkeling van die nuwe stelsel verduidelik. Die implementering en die validering van die stelsel deur die outeur, word beskryf en getoets deur middel van ’n eksterne sertifiseringsliggaam.

Hierdie studie poog om as riglyn te dien vir die fokus groep (klein- tot mediumgrootte ondernemings) en hul kennis van die AS 9100 standaard te verbreed. Hierdie kennis dra potensieel by tot die ontwikkeling van hul eie gehaltebestuur stelsels en die implementering van AS 9100 vereistes sodat akkreditasie tot die standaard verkry kan word en hul die lugvaartnywerheid kan betree. Die dokument beskryf die historiese agtergrond en huidige gebruik van die AS 9100 standaard.

Die doel van die gevallestudie is om die generiese waarde van die metode vas te stel sodat ander klein tot mediumgrootte ondernemings in staat sal wees om dieselfde metode te volg om AS 9100 te implementeer.

Die metode se geldigheid en sukses word bepaal deur middel van 'n eksterne oudit (sertifiseringsoudit) van die navorsingsvennoot in die gevallestudie. Die metode maak gebruik van 'n spesifieke IT-gebaseerde infrastruktuur om die vermindering van onnodige dokumentasie te fasiliteer. Ervarings en bevindings van ’n soortgelyke studie in Swede, waar die outeur lid van die implementeringspan was, word ook kortliks bespreek om die geldigheid van die generiese stappe te bepaal en te beklemtoon.

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Glossary

SME	Small to Medium Sized Enterprise
DTI	Department of Trade and Industry
IAQG OASIS	International Aerospace Quality Group Online Aerospace Supplier Information System
CSIR	Council for Scientific and Industrial Research
TC	Technical Committee
CB	Certification Body
MR	Management Representative
QMS	Quality Management System
CR	Contract Review

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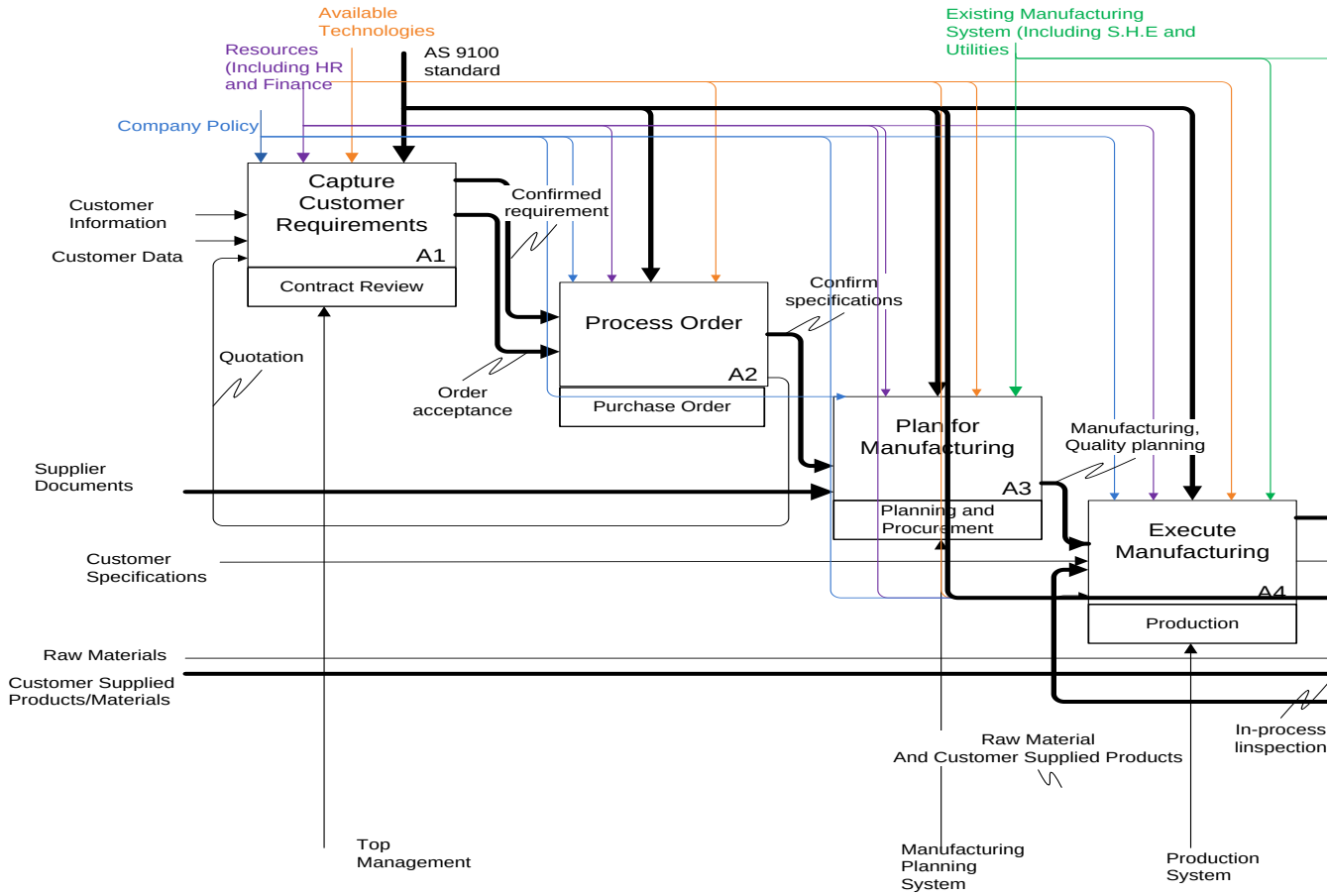

1. Introduction

1.1 Context of the Problem

As a country that supplies components to the global aerospace industry supply chains, as well as directly to OEMs like Airbus, Boeing and Cessna which are first tier suppliers, South Africa has the potential to grow extensively. The economic crisis had a significant impact on the growth of small- to medium-sized enterprises (SMEs), including aerospace companies. Before the recession, SMEs did not recognise the necessity to become certified with internationally accredited quality standards, as there was an abundance of business opportunities. In the current restricted business climate, SMEs are increasingly realising the importance of certification. The standard that aerospace companies need to comply with is the AS 9100 standard. Compliance with AS 9100 was previously considered a competitive advantage (order winner), but has become a necessary prerequisite (order qualifier) to be considered for a contract. AS 9100 certification was imposed not only on SMEs who want to gain entrance to the supply chain but also on first tier suppliers to OEMs. An example of first tier suppliers like this in South Africa are Denel and Aerosud.

In the aerospace industry, accountability, traceability and documentation are of critical importance. The trend in improving a company's processes is to scale down on excess documentation. In the case of aerospace companies, this is an extremely challenging goal, because traceability is of such crucial importance in this sector. Manufacturing history should enable tracing the final product/part back to the very start or to a specific batch when one part of the batch has failed. The quality of the product according to the customer and standard specification is crucial as it has a significant effect on safety in terms of structural, -system and –operational integrity. In addition, other parts of the batch need to be traced forward to find the location of the other parts and to suspend their use pending further notice. Many OEMs and international standard and recommended practice (SARP), require traceability back to the origin of the raw material.

This study provides a background of quality management systems in the aerospace industry. It describes the historic background and current use of the AS 9100 standard. A case study and generic method to implement AS 9100 at a small- to medium-sized aerospace supplier are presented. The method makes specific use of an IT-based infrastructure to facilitate the reduction of unnecessary documentation. The method's generic value is validated by means of an external audit of the company in the case study. The author's experiences in applying aspects of the method used to upgrade automotive suppliers to aerospace suppliers in Sweden are briefly discussed.

1.2 Research Gap

Table 1: Trade of aircraft, spacecraft and parts (R millions)

(DTI database)

	2003	2004	2005	2006	Average annual growth rate
Exports	796	1,210	4,254	4,018	49.9%
Imports	9,336	11,806	9,510	5,379	-12.8%

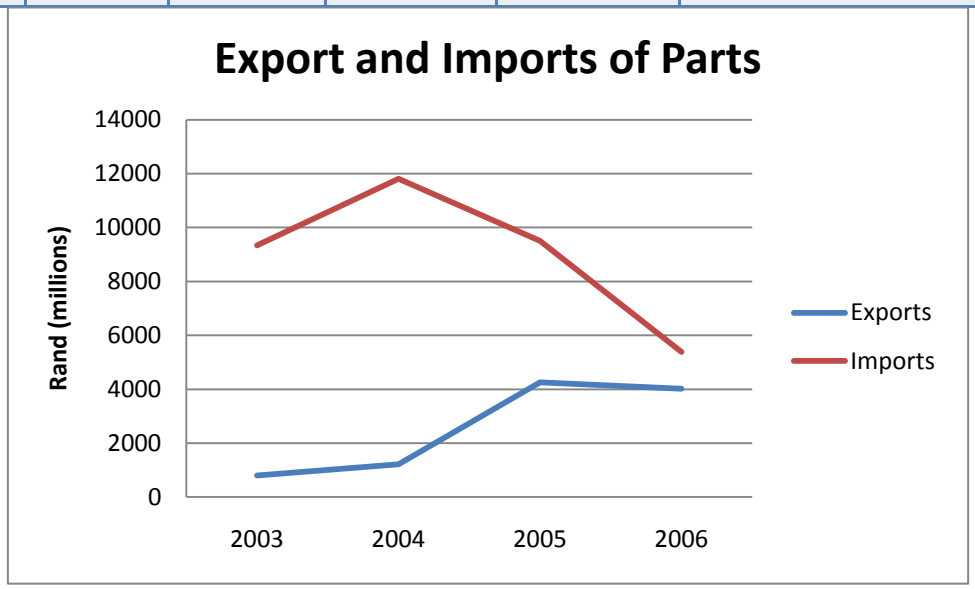

Figure 1: The exports and imports of aircraft, spacecraft and parts

Table 1 and figure 1 indicate the increase in exports and decrease in imports over the years described in the DTI database (2003-2006). According to the data, exports of aircraft, spacecraft and parts grew substantially over this period: exports grew by 49.9% p.a., while the imports decreased by 12.8% p.a. This indicates that South Africa is starting to produce a larger value of parts locally and exporting it to customers abroad. (Soko 2006)

Table 2: Causes of fatal accidents (percentage %)(www.planecrashinfo.com)

Cause	1950s	1960s	1970s	1980s	1990s	2000s	All
Total Pilot Error	58	55	42	44	52	45	50
Other Human Error	0	8	9	6	8	9	6
Weather	16	10	13	15	9	8	12
Mechanical Failure	21	20	23	21	21	28	22
Sabotage	5	5	11	13	10	9	9
Other Cause	0	2	2	1	0	1	1
Total (100%)	100	100	100	100	100	100	100

As seen in the table above, mechanical failure is the second largest cause of fatal accidents. In view of this hard fact, the aim is to come up with a plan to ensure product quality all the way through – from the very start of the manufacturing process up to the final product: the aircraft.

The research gap for research and development of the South African aerospace industry was emphasised by the Head of CSIR Aerospace Initiative, Beeuwen Gerryts, in the article, *South African Aerospace industry should be seen as a 'national university'*. According to Gerryts, South Africa is a developing country and based on this fact it must realise its ability to stimulate education and research and development (R&D), in this process creating skilled and specialised jobs while also encouraging the development of advanced manufacturing. (Campbell 2010)

Globalisation of markets, manufacturing, and research and development are all prominent current trends in global aerospace. The world's leading aerospace manufacturing companies have a global supply chain with proven and trusted partners as lower-tier suppliers. The long lifespan of aircraft marks this as a very complex industry that is becoming more complex as technologies improve.

Gerryts emphasises the importance of the country's coordination of national initiatives and projects, as well as the need for a conscious effort to strengthen the links between the local industry and the R&D community (Campbell 2010). The pressure on low-tier suppliers (manufacturers of subsystems and subcomponents) in terms of quality and cost has increased drastically and thus requires more investment in R&D, especially in SMEs.

In general, the South African aerospace industry is known for its innovative solutions. Regarding complete airframes, the country has two original-equipment manufacturers, Denel Dynamics and Advanced Technologies & Engineering (better known as ATE), who produce unmanned air vehicles (UAVs) and missiles. Denel Aviation holds the design authority for the Atlas C4M Kudu, Atlas Cheetah (C, D and E models), Atlas CSH-2 Rooivalk and the Atlas (AS332) Oryx. South Africa also has aerostructures and aircraft component manufacturers (Denel Saab Aerostructures and Aerosud), some small manufacturers of sports aircraft and gliders, and companies that manufacture avionics and sensors (Campbell 2010).

The South African government had placed an order for eight Airbus Military A400M strategic transport and air-to-air refuelling tanker aircraft, but cancelled this order in November 2009. This cancellation caused serious concern for the two companies in South Africa who already had established relationships with Airbus and significant work packages for the production of the A400M, initially awarded as countertrade. This situation is representative of the opportunities that countertrade can present, but illustrates the concomitant uncertainty of this type of international business.

The problem that SMEs struggle with is the lack of personnel and as a result they cannot devote a department exclusively to the implementation and management of quality. The "aerospace skilled" personnel in the aerospace industry are limited and leave room for concern. Not only have SMEs small numbers of employees, these employees are also not aerospace skilled personnel.

In aerospace, the manufacturing process mainly consists of short production runs and cannot be monitored in the same way as mass production. An opportunity was also born out of the demand for a closer supply chain network.

1.3 Research Objectives

The purpose of this study is to:

1. Compile a compact introductory guide and suggesting techniques for SMEs to facilitate lean management resource usage during implementation;
2. To investigate the role and requirements of AS 9100 in aerospace component manufacturing and business operations;
3. To develop a an IT-based AS 9100 quality management system at a specific small to medium sized company such that the result can be adapted to become a generic method for a similar South African company;
4. To perform an independent supplementary investigation to validate this method.

1.4 Formulation of the Research Question

How can SMEs gain entry to the aerospace industry by means of developing and implementing AS 9100 and become accredited?

This research question gives rise to the following lower-order questions:

Considering an SME's management level constrained resources, how can a quality system be implemented while a minimal additional management burden is placed on the SME?

How can IT implementation reduce the administrative cost and facilitate effective execution of procedures?

How can the implemented system accommodate revision changes as well as customer and regulatory requirements?

How should the quality system be structured such that conformance to AS9100 and ultimately accreditation are ensured?

1.5 Outline of this Study

Chapter 1- Introduction:

An introduction to the study is given with reference to the context of the problem, the research gap for the fulfilment of this study, as well as the objectives to be achieved after completion thereof.

Chapter 2 – Literature Review:

The literature that describes this study and served as guidelines in the next chapters is presented in this chapter. It gives an overview of the aerospace industry, strategic quality planning and the quality standard, AS 9100.

Chapter 3 – Methodology:

The methods which were used in conducting the research are presented in this chapter. An explanation of how the research tools were utilised in the duration of this study is given.

Chapter 4 – The Research Partner:

The industry partner who served as the case study for this investigation is described and analysed in this chapter to get a clear picture of their business and quality management activities.

Chapter 5 – Gap Analysis and Audit Methodologies:

The terms and concepts which served as guidelines in the auditing process are described. The steps followed in performing the internal audits as well as in observing the external audits are explained in this chapter.

Chapter 6 – Design and Construction of IT-based QMS:

The process of designing and constructing of the new QMS is explained in this chapter. It gives a clear picture of all the steps in the process with reference to the requirements addressed in each step.

Chapter 7 – Validation through Post-Implementation Follow-up Audit at the Research Partner:

Validation of the QMS and the implementation plan was done by means of an internal and external audit, as well as comparing the method to another case study example in Sweden which is explained in this chapter.

Chapter 8 – Conclusion and Recommendations:

This chapter summarises the results and observations of the outcome of the study.

2. Literature Review

In light of the development of quality assurance into globally accepted standards during the last two decades of the twentieth century, the study field has developed into a specialised academic field of study. However, South Africa still has a young academic focus with relatively few research studies completed locally. Previously, quality systems were dominated by customer- and product-specific requirements. The modern trend is for a globally accepted set of requirements to become the norm. This field of study has therefore developed to maturity with a large body of knowledge published in the academic domain, of which this chapter presents a cross-section. The chapter references the aerospace industry, especially small- to medium-sized enterprises in South Africa, and how to achieve strategic quality planning. The quality standard under investigation is AS 9100 revision C and a background and description of it are presented. The certification process is briefly described as a large proportion of SMEs have a need for this information. The chapter concludes with a perspective on the relevance of generic new developments in configuration management, as well as the Hoshin Kanri quality method.

2.1 The Aerospace Industry:

Paul Hatty (Hatty 2000) defines the South African aerospace industry as follows:

“The research and development, design, manufacture, support, maintenance, conversion and upgrade of: rotary and fixed wing aircraft; satellites, satellite launch and tracking systems; unmanned aircraft; and weapons systems as well as their relevant subsystems and components.”

The term ‘aerospace’ is used to refer to the industry that researches, designs, manufactures, operates and maintains vehicles moving through air and space.

2.1.1 Background

Table 3: Aerospace Industry Tiers

	Description	Level of skills
Top-tiers or first tiers		
Tier One (Complete system)	Entire aircraft with all the required sub-systems already fully integrated	High value-added products High-level human resources
Tier Two (Major sub-systems)	Sub-systems that are made up out of a significant number of minor sub-systems	Medium value-added products Medium-level human resources and production skills
Lower Tiers or Sub-Tiers		
Tier Three (Minor sub-systems)	Defined assembly of components indivisible into other systems	Medium value-added products Medium-level human resources and production skills
Tier Four (Components)	Devices with a clear function that are of no use unless integrated into a tier-three system	Medium value-added products Medium-level human resources and production skills
Tier Five (Parts)	Units that can be defined as a single monolithic part	Low value-added products Medium-level human resources

The competitive pressure that tier-one producers face results in lower-tier suppliers taking on more responsibilities to develop their own systems integration skills and taking greater financial risks, as well as enforcing much stricter quality control standards and raising the competitiveness of their product support (Haupt 2005). In earlier years, the top-tier

producers carried most of the risks on their own and they alone were certified against the strict quality regulations. The rapid growth of the aerospace industry has caused the transfer of responsibility to the lower tiers in the supply chain to be able to optimise production and decrease the high risks and inspection time for the top tiers.

The advantage for the lower-tier manufacturers is that certification to international quality standards makes them more competitive and assures top tiers of their capabilities.

The Sectoral Analysis of the Aerospace Industry in South Africa emphasized the importance for lower-tier companies to multiply their efforts in order to adapt to the new terms of competition with new skills and technological capabilities and earn accreditation to the international aerospace quality standards (Kreamer-Mbula 2008).

According to the DTI an SMME may include micro-enterprises, survivalist enterprises, informal sector enterprises, and formal, small and medium-sized enterprises. It also covers businesses in all stages of evolution, from pre-establishment to start-up, emerging, stable or expanding, as well as enterprises in distress. (Department of Trade and Industry 2005)

The same study stated that it is difficult to assess this sector because of the lack of consistent and comparable data. However, interest in this sector is growing significantly in policy circles. Various sources suggest that there are currently between 100 and 200 domestic organisations engaged in aerospace activities in South Africa. The sector is highly concentrated in a few, very large organisations, although the segment of small, medium and micro enterprises (SMMEs) is rapidly growing and has recently been estimated to comprise approximately 75% of the number of organisations. South African aerospace companies mainly operate in the province of Gauteng, while a smaller hub is based in the Western Cape and connected to Stellenbosch University (Kreamer-Mbula 2008). According to the International Aerospace Quality Group (IAQG) website, there are currently only eleven companies in South Africa certified to the AS 9100 standard. As shown in table 4, this leaves between 90 and 190 companies who still requires AS 9100.

Table 4: Opportunities for Certification

	100 Lower Estimate	200 Upper Estimate	11Certified Companies (IAQG)	Total Opportunity
SMEs (75%)	75	150	(3)	72-147
Bigger Aerospace Companies (25%)	25	50	(7)	18-43

Focusing especially on the smaller firms (SMEs), the key to successful competition in the global supply chain is to become the “best partner” to the biggest players, according to Dr Anders Skyttebol of the Swedish aero engine manufacturer, Volvo Aero Company(Campbell 2010).

2.2 Background on the Concept of Manufacturing Quality

Quality is the measure of excellence or the state of being free from defects, deficiencies and significant variations. The ISO 8402-1986 standard defines quality as “the totality of features and characteristics of a product or service that bears its ability to satisfy stated or implied needs.” According to the Business Dictionary-website, quality in manufacturing is defined as the strict and consistent adherence to measurable and verifiable standards to achieve a uniformity of output that satisfies specific customer or user requirements (Business Dictionary, 2010).

Interest in the concept of quality has grown steadily resulting in a legacy of business success since the 1970s. The leader pioneering this concept is undoubtedly the Japanese automotive industry. This can be accredited to the strategic role played by Japanese business leaders, who realised that there was a need to build on customer needs and expectations, and that the cost of modifications, rejections, delays and safety stock buffers were exceptionally high. (Johansson, Stenmark 2005)

The concept of quality is defined in a variety of ways. The Japanese quality expert, Genichi Taguchi believes that "non-quality” costs are the society's total losses caused by the product after its delivery. Johanssen and Stenmark define a product’s quality as "its ability to satisfy, and preferably exceed, the customer’s needs and expectations". (Johansson, Stenmark 2005)

Within the aerospace industry, factors such as quality, safety and reliability are very important because deficiencies in these can have devastating and costly consequences. The complicated manufacturing process and the rigorous safety requirements in the industry place high demands on quality work.

2.3 Introduction to Quality Management Systems:

According to ISO 9000:2000, a system is a “set of interrelated or interacting elements” and a quality management system is defined as “a management system to direct and control an organisation with regard to quality”.

In the 1930s, a military distributor in the U.S. developed a standard for how a supplier should assess activities for quality work. This standard requirement came to be known as ‘’quality” and later led to an international standard for quality system known as ISO 9000. It is now

common for companies to demand that their suppliers have a documented quality system (Johansson, Stenmark 2005). The term ‘quality system’ is defined in ISO 9000:1994 as "an organizational structure, procedures, processes and resources necessary for the conduct and management of activities relating to quality". A company's quality system constitutes a basis for controlling and improving the quality of the organisation's products and processes, while it should be documented to the extent that it can support work and serve as a base for the quality objectives of the organisation (Johansson, Stenmark 2005).

It could prove to be difficult to identify and locate the exact cause of problems in a company’s quality department. It is time-consuming to investigate all these problems individually and set preventive plans into action to avoid reoccurrence. A well-managed and maintained quality management system can prevent this tedious process(Fakhri 2010).

The main objective of an organisation will always be to satisfy the requirements and expectations of the customer. A quality management system refers to those activities that enable the company to achieve this. It is a complete system that works on the following principles (Fakhri 2010):

- Establish

Establish the exact requirements of the customer and the processes needed to achieve them.

- Document

Document the work flow of these established processes.

- Implement

Utilise the processes effectively to achieve the requirements.

- Maintain

Maintain these processes, evaluate and measure the results continually.

- Continual Improvement

The continuous evaluation and measurement of the processes will point out opportunities for improvement.

Quality management in an SME organisation is often shifted to the last part on the agenda or priority list because of the small number of management personnel and their large and diverse workloads. The difference is that larger organisations have entire teams that are

employed for the specific task of quality management. Quality management as a topic is often erroneously addressed in an SME as an activity separated from daily production, instead of being the umbrella under which all the business's processes are carried out. The ideal would be to transform the whole organisation to have a mindset of total quality from start to finish, achieving zero defects (Kumar 2008).

2.4 Quality Strategy:

A business consists of a number of dimensions and one of them is quality. Like all the other dimensions, it should be managed strategically. It happens regularly that the focus of quality improvement efforts is mainly on tools and methods that will improve specific processes, and the business completely overlooks the impact that quality has on the business as a coherent whole. The ideal would be if these efforts enabled a holistic view of the business (Harun, Cheng 2010).

2.5 Background/Research on how quality links with strategy

There are a large number of approaches that can be followed to achieve good quality, and all of them can be combined to create a quality system. Most businesses have a quality management system that enables them to keep track of the quality of their internal and external processes (Fakhri 2010). This quality management system usually takes the form of a document that contains the company's vision and mission statement, a description of what the business of the company is, and the procedures that describe the processes of each department/step in the production of the final product. There are quite a variety of literature sources that can offer support material when planning the implementation of a quality management system. G. Dennis Beecroft from the Institute for Improvement in Quality and Productivity at the University of Waterloo, Canada, wrote an article focusing on "The role of quality in strategic management". This article, as well as other literature which will be referenced at a later stage, were analysed to see how strategy and quality can be linked (Beercroft 1999).

2.6 Strategic Quality Planning:

Strategy is a long-term action plan for achieving a goal. In this case, the goal would be to become a business known for its superior quality and therefore increased customer satisfaction, which, in turn, will increase the market share. Management of strategy implies the systematic analysis of the factors associated with the external and internal environments to provide the basis for rethinking the current management practices. Its objective is to achieve better alignment of corporate policies and strategic priorities. In the case of quality: how can the external and internal implementations of quality be managed in the day-to-day environment to achieve the long-term goal of quality excellence for the business as a whole?

The aim of this analysis is mainly to determine how strategy and quality can be linked to each other. "Organizations need to expand their business planning approach to link their strategic vision, short- and long-term business goals and their quality improvement initiatives" (Beercroft 1999).

2.6.1 Developing a quality strategy

When the quality strategy of the enterprise is developed, all the vital parts must be included to ensure a superior quality management document that can be used as a guide to achieve the long-term goal of top quality. These parts include quality mission, vision and/or policy documents. Depending on the type of organisation, there are certain guidelines and standards that can be used to develop their quality management system. Examples are the ISO standards and AS standards (for aerospace industries). The expectations of the organisation should be very clear in order to build a quality process. It should be written in such a way that all the employees know exactly what are expected of them and why they are performing certain duties. When a person (in this case, the employee) knows why processes are structured in a certain way, and understands the bigger picture (long-term goal of quality), it becomes considerably easier to motivate them to work to target zero defects the first time. A quality strategy should have the outcome of a quality lifestyle that is lived every day.

2.6.2 Establishing goals and objectives

Before one can establish the goals and objectives, the core business must be assessed to have a full understanding of the current situation. An analysis of the situation will place emphasis on the need to have consistency among all the departments and functions that will enable them to focus on the business as a whole. To do this, the following must be evaluated:

- Business objectives
- External business environment conditions
- Resource availabilities

External business environment conditions include the investigation of the customer, the market, economy, politics, industry, technologies and competitors. The customer may include the stockholders and board of directors as well as the internal and external customer.

2.6.3 Identifying specific quality initiatives

The "management by objectives" approach alone is insufficient as a planning tool. The company needs to have a clear understanding of exactly what their targets and objectives are and then find out exactly what needs to be done to achieve them. It is more important to

determine how the goal is achieved (action plan) than focusing on the goal (target), because the plan can be modified if something goes wrong or a better plan is found.

2.6.4 Implementing a Quality Management System

Once the company is satisfied with the quality management strategy that they have developed, the action plans must be implemented, evaluated and maintained. This process will be described in more detail in the methodology phase of this thesis as the development of the quality management system. The maintenance of the system includes the continuous monitoring of the plan as well as any adjustments that need to be made for improvements and to reach the quality objectives.

The major clauses and sub-clauses of the current revision of AS 9100 quality management systems requirements are:

1. Scope
2. Normative references
3. Terms and definitions
4. Quality management system
5. Management responsibility
6. Resource management
7. Product realisation
8. Measurement, analysis and improvement

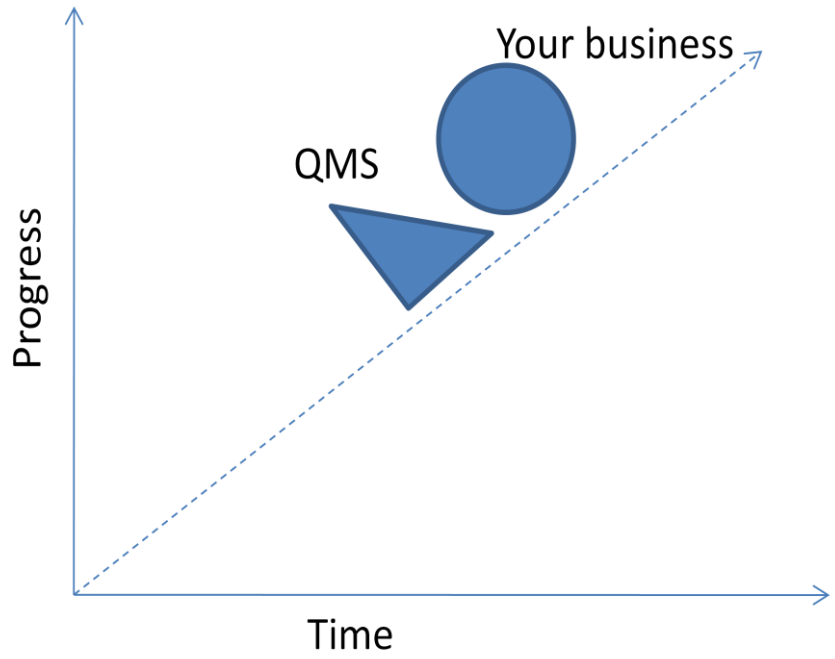

Figure 2: Wedge diagram of QMS (Department of Trade and Industry,2005)

The wedge diagram in figure 2 illustrates the necessity for an effective quality management system (QMS) that prevents a business from rolling back to a previous stage. Customer satisfaction is an extremely important factor for this manufacturing company and all companies in the aerospace industry. They apply their QMS with the intention of ensuring the provision of products that consistently meet the requirements of their customers as well as being a tool for continually improving the efficiency, competitiveness and profitability of the company.(Department of Trade and Industry 2005)

2.6.5 The role of the organisation's quality objectives

According to Beercroft, there are a number of quality objectives that a company may want to achieve (Beercroft 1999). Each company will have its own set of objectives with its own plans to reach it. This will be described later on in the study.

2.7 AS 9100 Quality Management Systems

2.7.1 Background (History)

According to Dale K. Gordon, former chairman of Americas Aerospace Quality Group, "the goal of the [AS 9100 quality management] system is for a supplier to receive one 9100 quality systems approval that will be acceptable to all aerospace OEMs throughout the world. The key element in this is confidence. The aerospace OEMs must have confidence in the approvals being given in other Sectors"(Coppinger 2003).

AS 9100 is the quality standard required for aviation, space and defence organisations. The Society of Automotive Engineers (SAE) published the first international quality system standard for the aerospace industry, AS 9100, in November 1999. It was developed by the International Organisation for Standardisation (ISO) Aerospace Technical Committee 20, together with the American Aerospace Quality Group (AAQG) in the United States and the European Association of Aerospace Industries (AECMA) in Europe and other countries, including China, Japan, Mexico and Brazil. Previously, a number of different standards were used in aerospace companies, but no single standard was globally acknowledged. The AS 9100 was the first globally acknowledged standard that addressed civil and military aviation as well as aerospace needs. It incorporated ISO 9000 requirements together with supplementary requirements specific to the aerospace industry.

Immediately after the AS 9100 standard became available, industry leaders, including The Boeing Company, General Electric Aircraft Engines and Rolls-Royce Corporation specified to their suppliers compliance with the standard as a vendor qualification requirement (Coppinger 2003).

The previous version, AS 9100 Rev B, was published in 2004 and included the ISO 9001:2000 requirements and format. The most recent revision was published in 2009 to incorporate requirements of ISO 9001:2008. The slight changes and additions in this version were a response to stakeholder needs (SAE Aerospace AS 9100C 2009).

The AS 9100 family also includes AS 9110, AS 9120 and AS 9101. AS 9110 is the standard for Quality Maintenance Systems – Aerospace – Requirements for Maintenance Organisations and is based on AS 9100 and adds specific requirements that are critical for the maintenance of commercial, private and military aircrafts. AS 9120 is the standard for Quality Management Systems – Aerospace Requirements for Distributors. AS 9101 defines the QMS Evaluation criteria for AS 9100C AS 9110A and AS 9120A, in the form of a checklist.

Table 5 below shows the historical developments of ISO 9000 and AS 9100, according to Graham, (2007) .

Table 5: History and development of AS 9100 Quality Standard (Graham 2007)

1957	Six European countries form Common Market (EEC)
1979	ISO 9000 TC (Technical Committee) 176 formed
1987	ISO 9000:1987 adopted by fourteen countries
1994	ISO 9000:1994 Second revision released
1996	Ninety countries adopt ISO 9000 as national standard
Jan. 1997	D1-9000:1997 Rev A released
Jan. 1998	AS9000:1998 released
Nov. 1999	AS 9100:1999 released
Dec. 2000	ISO 9000:2000 Third revision release ISO 9000 incorporates major organisational and philosophical changes; AS9000 rewritten
Jul. 2001	AS 9100 Rev A Update to ISO 9000:2000
Jan. 2004	AS 9100 Rev B Update to ISO 9001:2000 References to ISO9001/2, 1994 removed
Jan.2009	AS 9100 Rev C Update to ISO 9001:2008
May 2010	The IAQG-sanctioned Aerospace Auditor Transition Training

2.7.2 Description of the Standard:

AS 9100 is a set of requirements that must be achieved. However, the intention of the standard is not to imply uniformity in the structure of quality management systems or their documentation; rather, it gives guidance on how to meet these requirements.

After a business has decided to implement AS 9100, there are certain steps that need to be followed. This thesis is merely a framework that was investigated by the action researcher in order to simplify the process of implementation, especially for SMEs. It will provide the reader with a clear picture of the whole process, from the designing of their quality management system up to the acquiring of AS 9100 certification.

The latest revision of AS 9100 (revision C) specifies the requirements for a quality management system in aviation, space and defence organisations. The main purpose of an organisation in this industry should be to ensure customer satisfaction. To do this, organisations must produce – and continuously improve – safe and reliable products that meet or exceed customer and applicable statutory and regulatory requirements (SAE Aerospace AS 9100C 2009). The contemporary trend of geographically distributed supply chains has caused a challenge to organisations to purchase or deliver products at any level in this widespread supply chain. In earlier days, suppliers didn't have the difficulty of multiple customers having varying quality requirements and expectations, because the supply chain was relatively complex. As the supply chain expanded, and transport and technology became available for this, the opportunity developed for an aerospace standard to be used globally (Coppinger 2003).

The AS 9100 standard proposes to standardise quality management system requirements to a large extent. The standard can be used at all levels in the global supply chain. After the successful implementation of the standard, the quality should improve substantially. Better cost and schedule performance will be achieved because of the standardisation of requirements and the application of good practice. Companies will be able to reach an entirely new level of quality (SAE Aerospace AS 9100C 2009).

2.7.3 Focus Group:

The standard will be described in this study in such a way that the focus group (the SMEs) will know what the critical success factors for the development and implementation of an AS 9100 quality management system are. With this study the researcher aims to help SMEs understand their current quality status and then minimise the gap between the AS-IS situation and an AS 9100 certified company.

The most common obstacles for SMEs are their size and financial resources. They are too small to have a department solely dedicated to handling all the quality aspects of a business and even if they want to subcontract some of these tasks to an external party, it is very often prohibitively costly. Even if it is affordable, the problem of ownership of processes is encountered. If a consultant is relied upon to stand in for process ownership, the benefits are seldom sustainable and the opportunity to grow a quality mindset in the business will probably be missed (Kreamer-Mbula 2008).

The importance of participation and assistance from an organisation in identifying work procedures in the planning phase of a QMS is a key issue. The procedures affect the quality of the product or service that in return affects the requirements of the customer. The positive effect will be improved work processes. Typically, some procedures or instructions are never documented, even if they have been carried out for a long time. This should be addressed in this phase and be documented to have traceability to every step of each process. According to secondary literature (Godwin 2002), important factors to take into account when planning a QMS implementation, are:

- The business's participation and assistance when process mapping of work procedures are done
- Continual improvement of work procedures
- Documentation of procedures and work instructions
- Data and recordkeeping for traceability
- Participation in internal audits
- Participation in ongoing process improvement
- Participation in external registration and surveillance audits to achieve registration

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2.8 Overview of the AS 9100 Revision C Standard:

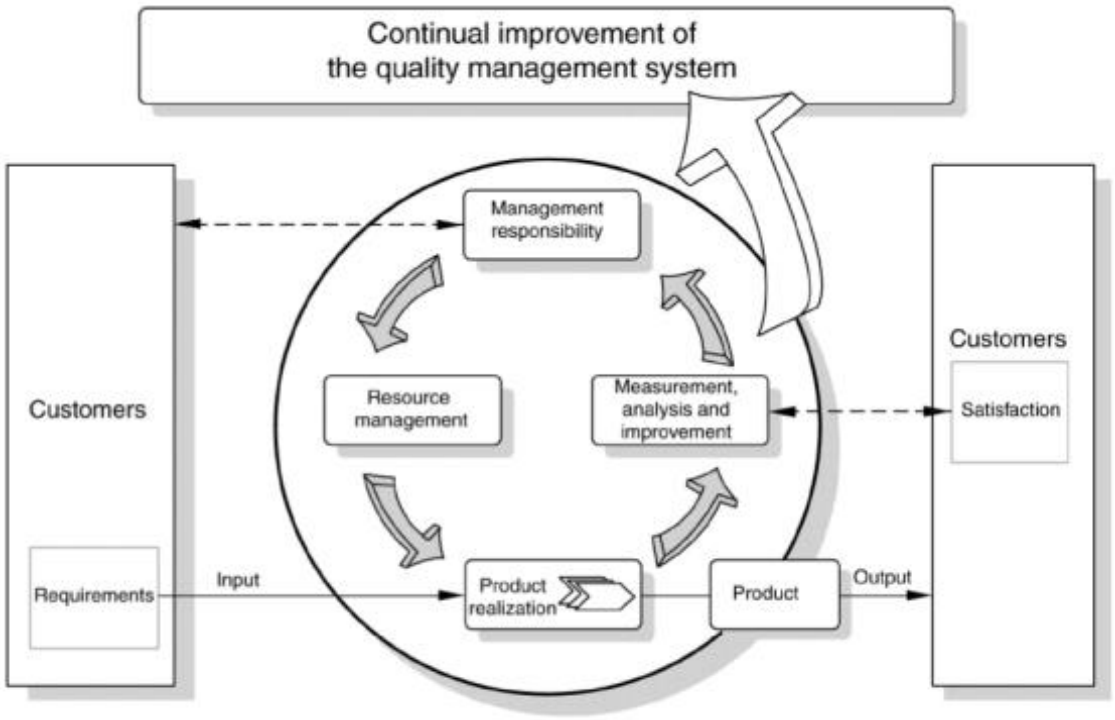

Figure 3: Process oriented cycle of the AS 9100 Standard (SAE Aerospace AS 9100C 2009)

2.8.1 Clause 1: Scope

The AS 9100 Revision C standard (illustrated in figure 3), includes ISO 9001:2008 quality management requirements with additional requirements from the aviation, space and defense industry (SAE Aerospace AS 9100C 2009).

2.8.2 Clause 2: Normative References

The "*ISO 9000:2005, Quality management systems – Fundamentals and vocabulary*" is indispensible for the application of this document (AS 9100).

2.8.3 Clause 3: Terms and Definitions

The same terms and definitions as for ISO 9000 apply and risk, special requirements, critical items and key characteristics are defined in this Clause.

2.8.4 Clause 4: Quality Management System

This clause describes the broad picture of the company and the general information about quality management system (QMS), and defines the requirements of a QMS. It requires identification of processes, their sequence and interaction, criteria for control of processes, availability of resources, monitoring and measurement, as well as its continual improvement. Documentation needs, quality manual, control of documents and control of records are addressed.

2.8.5 Clause 5: Management Responsibility

This section defines the responsibilities for top management. This is a key section, as all authority flows down from top management. It addresses customer focus, quality policy, planning, responsibility, authority and communication, and management review. Management reviews are a key factor for sustaining the QMS. Management looks at the system as if it is "looking at the forest" whereas internal auditors are "looking at the trees".

2.8.6 Clause 6: Resource Management

The need to provide resources for the execution of work and for continual improvement is defined in this section. This clause addresses human resources in terms of their competence, awareness and training for specific skills. The infrastructure includes the buildings, workspace, utilities and equipment, as well as supporting services. The work environment will be assessed in terms of its cleanliness, sound and safety – in other words, the ergonomics.

2.8.7 Clause 7: Product Realisation

The term product can also refer to service in this standard. This section focuses on the whole production process from start to finish. It includes the following actions:

- Planning
- Customer related processes
- Design and development
- Purchasing
- Product or service provision
- Control of monitoring and measuring equipment

2.8.8 Clause 8: Measurement, Analysis and Improvement

This section focuses on the need to monitor and measure the following product (service) processes:

- Need to assure product (service) and QMS conformity
- Customer satisfaction measurement
- Internal audits (looking at the "trees")
- Process and product monitoring and/or measurement
- Control of nonconforming product
- Analysis of data
- Improvement (Continual improvement, corrective action and preventive action)

2.9 Certification Process

2.9.1 The External Audit Checklist: (AS 9101 D)

After an organisation implements AS 9100, it has to be certified by an external quality organisation (Certification Body). The auditor then audits the company with the support of this AS 9101 checklist to ensure conformance to AS 9100. If the company conforms to the standard and receive certification, it is valid for three years.

Figure 4: QMS audit process (Ramly, Ramly,E.S., Yusof,S.M. 2008)

2.9.1.1 Document Review

The first step is the assessment of the documented system. It needs to be compared with the requirements of the AS 9100 standard. The documentation must be approved before quality certification can be granted. The document review is normally conducted on-site. The AS 9100 audit process involves interviewing employees at all levels and reviewing records.

The quality certification assessment for AS 9100 has two main goals:

- Validating system compliance and implementation
- Determining system effectiveness

When the company applies for AS 9100 certification there is a certain process that needs to be followed, which consists of the following phases:

1. Preliminary contact visit (only required during initial audit or transfer of certification)
2. Stage 1 Audit (only required during initial audit or transfer of certification)
3. Stage 2 Audit (only required during initial audit or transfer of certification)
4. Surveillance Audit
5. Re-certification Audit

Preliminary contact visit will be held at the premises of the organisation to gather the required information for the stage 1 Audit.

Stage 1 Audit (Initial Audit and Certification)

The certification body (CB) will appoint a team leader to conduct the initial audit of the business. The team leader will require the necessary information and documentation prior to the on-site visit for review, including:

- Quality manual
- Description of the processes showing their interaction and sequence, as well as identification of any outsourced processes
- The last twelve months' performance measures and trends
- Proof that the requirements of AS 9100 standard are addressed by the organisation's documented procedures (this proof can be in the form of a cross-referencing matrix)
- Interactions with support functions on-site or at remote locations
- Evidence of internal audits of processes/procedures, including internal and external quality management system requirements
- The latest management review results
- List of all relevant major aviation, space, and/or defence organisations and any other customers requiring AS 9100 standard compliance
- Evidence of customer satisfaction and complaint summaries, including verification of customer reports, scorecards and special status or equivalent

During stage 1 audit the exclusions from AS 9100-series standards are addressed as well as the justification thereof. Only exclusions from clause 7 are permitted and should be satisfactory justified by the organisation and approved by the CB.

The CB will review the status of the areas of concerns to determine preparedness for the Stage 2 audit.

Stage 2 Audit:

This audit follows the first audit after issues identified during the first audit have been resolved. After the activities of the Stage 2 audit, including all nonconformities, have been closed and verified by the audit team, a recommendation for certification can be made.

Surveillance

A surveillance audit is an audit where all the applicable quality management system standard clauses (except the exclusions) are audited. This means that the organisation's processes that are part of these clauses will be audited within one certification cycle. The audit team will determine the audit method after it has reviewed the quality management system performance and its outcome.

Surveillance assessments are the heart of the post-certification process for AS 9100 certification. They assure ongoing conformity, determine whether the management system remains effective and encourage continual improvement, thereby helping enhance profitability. The last surveillance audit is always a recertification audit to ensure accreditation conformity and full assessment of the requirements.

The audit plan for the surveillance audit will consider changes in the organisation. Detailed audit findings, including reference to the audited processes, process documentation, and associated records, will be documented.

For surveillance audits, the audit team leader will advise in the audit report whether the recorded nonconformities constitute grounds for suspension of the certificate. An organisation's failure to demonstrate effective corrective action to deal with repeat nonconformities, its lack of actual performance data or of operational control, would warrant suspension of the certification (ASE International Group, AS9101D 2010).

Recertification

At least three months prior to the expiry date of the current certificate, the organisation must plan to have a recertification audit. The 'scope of certification' will be verified prior to each recertification audit. Any change in the customer approval status will be reviewed by the audit team to determine the impact on the certification status.

Once every three years, during the third year of each three-year certification period, the certification body will assess the quality management system in its entirety. The duration of this re-assessment typically equals about two-thirds of the audit days required for the initial assessment. By assessing the entire QMS during one assessment activity, the relationship between all the processes comprising it can be fully evaluated for effectiveness. (Smithers Quality Assessments 2010)

Special Audits

This is an audit in response to a customer or other interested party request, when the organisation requests to change their scope of certification, or when the organisation transfers to certification from one CB to another. These audits can be performed any time during the certification cycle.

Non-conformances

Major

According to AS 9101 D, a major nonconformity is a non-fulfilment of a requirement which is likely to result in the failure of the quality management system or reduce its ability to ensure controlled processes or compliant products/services (ASE International Group, AS9101D 2010).

Minor

According to AS 9101 D, a minor nonconformity is a non-fulfilment of a requirement which is not likely to result in the failure of the quality management system or reduce its ability to ensure controlled processes or compliant products/services (ASE International Group, AS9101D 2010).

2.10 Quality Tool: Hoshin Kanri

2.10.1 Introduction to Hoshin Kanri:

When strategic management is practiced efficiently, the following four objectives are achieved:

- Focus
- Alignment
- Integration
- Review

It is a common phenomenon that there is insufficient linkage between the achievement of top management goals and the daily management at operational level. A generic tool that can be used in critical business processes is the Hoshin Kanri system approach. It is a Japanese planning model, which is sometimes referred to as “management by policy”, “hoshin planning” or “policy deployment”. The Hoshin Kanri approach achieves all four of the above-mentioned objectives and is based on a step-by-step planning, implementation and review

process. Since it is a generic model, it can easily be used in strategic quality management. This model offers a planning structure that will bring selected critical business processes up to the desired level of performance – in this case, the business process is quality (Akao 1991).

Hoshin Kanri is applied at two levels:

- The Strategic Planning Level
- The Daily Management Level

2.10.2 The Strategic Planning Level:

A small number of key long-range corporate objectives are planned systematically. They are called Breakthrough Objectives, and typically last two to five years with little change. They are directed at achieving significant performance improvements, or at making significant changes in the way an organisation, department or key business process operates. According to Beercroft (1999), strategic planning has three levels:

1. Corporate Strategy
   - Vision
   - Corporate Goals
   - Philosophy and Culture
2. Business Unit Strategy
   - Mission
   - Business Goals
   - Competencies
3. Functional Strategy
   - Information Systems
   - Research and Development
   - Manufacturing
   - Finance
   - Marketing
   - Human Resources

2.10.3 The Daily Management (or Day-to-Day) Level:

At the daily management level, most of the time in an organisation must be devoted to keeping the business running and carrying out the value-added activities of the key business processes that fulfil the purpose of the organisation. These day-to-day business fundamentals should be monitored on a daily basis in all parts of the organisation. This is

how the process owners are able to take real-time corrective action for continual process improvement (Akao 1991).

2.10.4 The Generic Model:

The Hoshin Kanri model has four parts (which can be seen in figure 5):

1. Top management formulates a vital few strategic priorities
2. These strategic priorities are translated into action plans for the coming year by other management and grass roots employees
3. Routine daily management, when plans are managed at an operational level
4. An examination of policy and strategy in an organisation-wide review of performance

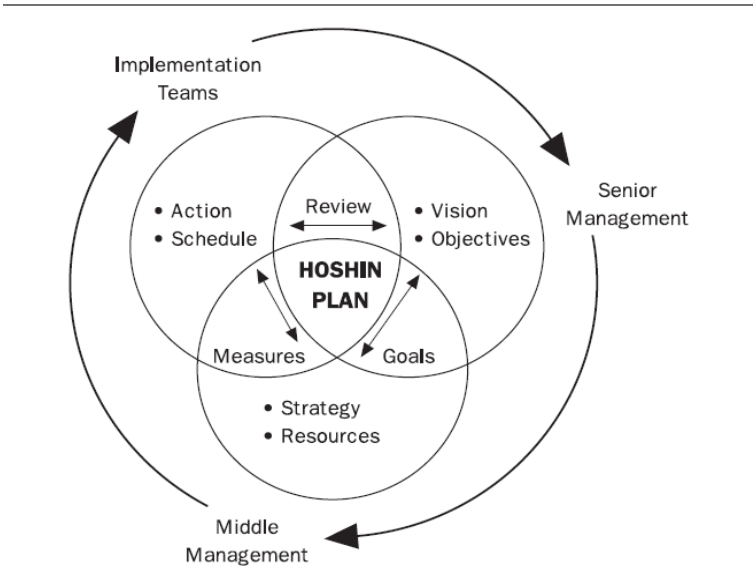

Figure 5: The Hoshin Kanri Model (Akao 1991)

2.10.5 Steps in the Hoshin Kanri Process

- Annual policy and medium- to long-term policy
- Basic company philosophy and quality policy
- Converting methodological policy into objective policy
- The composition of policy
- Two deployment styles of target: top-down and bottom-up
- Target deployment and "catch-ball": A discussion process before policy is finally decided during which the policy ball (draft policy) is thrown back and forth between top and middle managers before a final decision is made
- Top management internal quality control audit

2.10.6 Initial Considerations

The initial considerations in the Hoshin Kanri approach to business system change are as follows:

- Measure the business system as a whole
- Set the core objectives of the business
- Understand the environmental situation in which the business operates
- Define processes that make up the system, their activities, goals, and metrics
- Provide resources to perform activities that achieve business and quality objectives.

2.10.7 The role of Hoshin Kanri in a business

Where does this approach fit in with strategy and quality? It is used in the planning of the core business objectives, as well as in the day-to-day operations, to achieve quality throughout the whole process. It is continuously monitored, and revised when necessary, in order to achieve the goals that were set at the beginning of the planning phase. This method of continuous monitoring and revision is followed in the case study at the SME under investigation.

2.11 Configuration Management

The dynamic time dimension of the design, manufacture and support of a product can be supported by a technique called configuration management. This subject is also referred to as documentation version control, or by the more recent term, product life cycle management. The standard that gives specific guidelines to configuration management is ISO 10007. Configuration management is a discipline that applies technical and administrative direction to the development, production and support life cycle of a configuration item and the term is used in this sense in ISO 10007; it is applicable to hardware, software, processed materials, services, and related technical documentation (ISO 10007 2003). Configuration Management is a management tool that defines the product, and then controls the changes to that definition (Burgess 2005).

According to the article, “Configuration management in the aerospace industry: A review of the industry practice”, T.F Burgess explains that the key to configuration management is founded on good business sense and straightforward practice in handling documentation.

The need for configuration management has been established for a long time; it is still increasing and becoming even more crucial. The deficiencies in the control of the depth and uniformity of documentation came into focus in the USA during the late 1950s in the competitive production of reliable, working missiles (Burgess 2005). The need to keep

records of part identification, build statements, the changes implemented and technical publications that reflect build standards was identified and the processes in these key areas are still being improved. Guess (1995) stated that the life cycle of a product begins with the release of the first definitive document and ends with the retirement of the last definitive document. This is extremely important in the aerospace industry. When anything goes wrong, the problem needs to be traceable to the very beginning of that part's life cycle, and to all the parts in that specific batch.

Life cycle phases differ from industry to industry. In the aerospace industry, life cycles can exceed 50 years and this longevity can create problems because of the rapidly changing technology that stores records in digital format. Records can also become obsolete.

2.12 Visual Management

The methods and formats in which information are displayed or presented to the employees of a business are becoming very important in contemporary business practices. The way in which information, documentation or instructions are presented can greatly influence the employees' attitude towards the company. If such information and instructions are displayed attractively and in a way that is user-friendly, the probability is enhanced that it will be read and followed. A company's visual management system must contribute to the streamlining of the business and production operations. This can include the physical appearance of the business as a whole: the layout of the factory, with visual production, maintenance, inventory and overall quality control (Tompkins 2003).

When a quality management system is designed, including the quality manual, the visual documentation must be presented in such a way that it can be:

- Easily understood or straightforward
- User-friendly
- Configured
- Interlinked
- Audited
- Accessible
- Updated

3. Methodology

The methods used to conduct the research for this study are described in this chapter. It gives an overview of the general approach to this research. The research approach for this study was a qualitative study and utilised several research tools. The case study was described as a form of investigation and the author took part in solving a problem. This may be referred to as action research. It was performed in collaboration with design research and the data collection methods are explained with specific reference to document review and interviews.

3.1 Research Approach

3.1.1 General

As this research field is fairly new and there does not exist much literature on the AS 9100 aerospace quality standard, a qualitative approach was chosen for the research. In the qualitative method, data collection can be based on soft data in the form of interviews, as well as documentation and their analysis and interpretation. Qualitative methods are particularly appropriate when a pioneering study is performed in a certain field. Since the study aims to investigate the possibilities of generalising a plan to implement AS 9100 in SMEs, it seeks understanding of and insight into the problem and its solution. Therefore, during the work, qualitative data was collected through the examination of the research partner's quality management system and relevant documents, as well as interviews with personnel and observations of leaders in the aerospace supply chain.

3.1.2 Investigation

A case study is used as a form of investigation, and in the process the findings and observations are analysed. A case study focuses on an event and goes into some depth to explain the factors affecting the event. The case study examines an entity such as a company in a variety of ways. The case study therefore examines a well-defined phenomenon. A potential limitation of this study is that it can be difficult to generalise the case and therefore the value of the contents is also weakened (Johansson, Stenmark 2005).

3.1.3 Action Research

Action research is the optimum way to perform a case study. A system, company or situation is examined as a coherent whole, while an answer to the research question is sought. The action-research scientist has a role similar to a consultant and is able to find a possible answer whilst examining the process that is studied. Unlike traditional research, where the researcher is clearly separated from the object of the study, the action researcher

is deeply involved in and influencing the situation that is being studied. The researcher may implement certain recommendations in the process and test their reactions to find the most suitable solution for the case study. Action researching may also be seen as a change project because of the continuous "trial and error" approach that is followed. It is a project that may be optimised consistently if used for a significant period of time. Researchers cannot use existing theory alone to analyse the collected data in a scientific way, but should also produce useful knowledge for the subject under consideration. The researcher and the people who are in the environment that is being researched learn from each other and help each other develop skills while solving problems together.

Rapoport (1970) defined action research as the method that aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework. Susman (1978), described the process of action research as a cyclical process. The cyclical form, depicted in figure 6, with five phases is performed as many times as needed to find a solution to the problem.

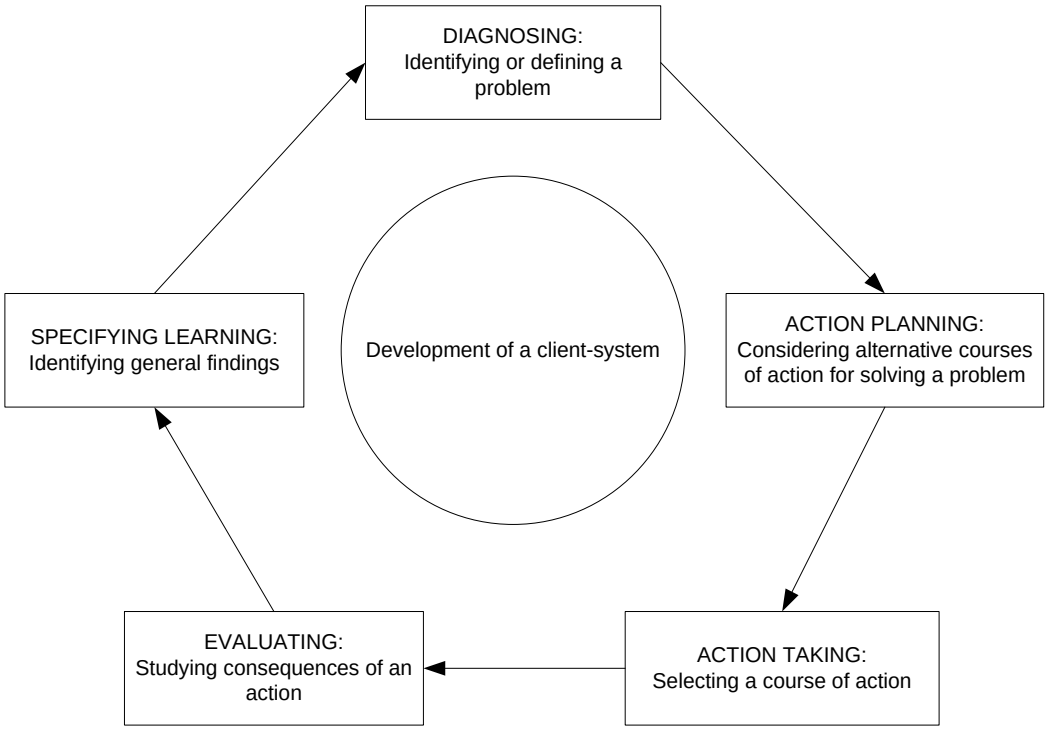

Figure 6: The cyclical process of action research (Susman 1978)

According to Susman (1978), action research:

- is future oriented
- is collaborative
- implies system development
- generates theory grounded in action
- is agnostic; and
- is situational

Over the course of the action research project, knowledge is generated, used, tested and modified. In the case of this thesis, it can be combined with design research. The objective is to analyse and find a better solution by developing, testing and implementing the new quality management system. Design research is henceforth explained in more detail to determine how the combination of these two research methods can collaborate with each other.

Design Science

Design science attempts to create things that serve human purposes and are technology-oriented. Its products are assessed against criteria of value or utility to determine if it works and whether it is an improvement(Baynes 1982). In the build activity, Jarvinen (2007), sees conceptual development as a category of constructive research methods refers to the development of various models and frameworks that do not describe the existing reality, but rather assists to create a new one, (figure 7 illustrates the methodology followed in this research method). Conceptual development produces the description of the desired

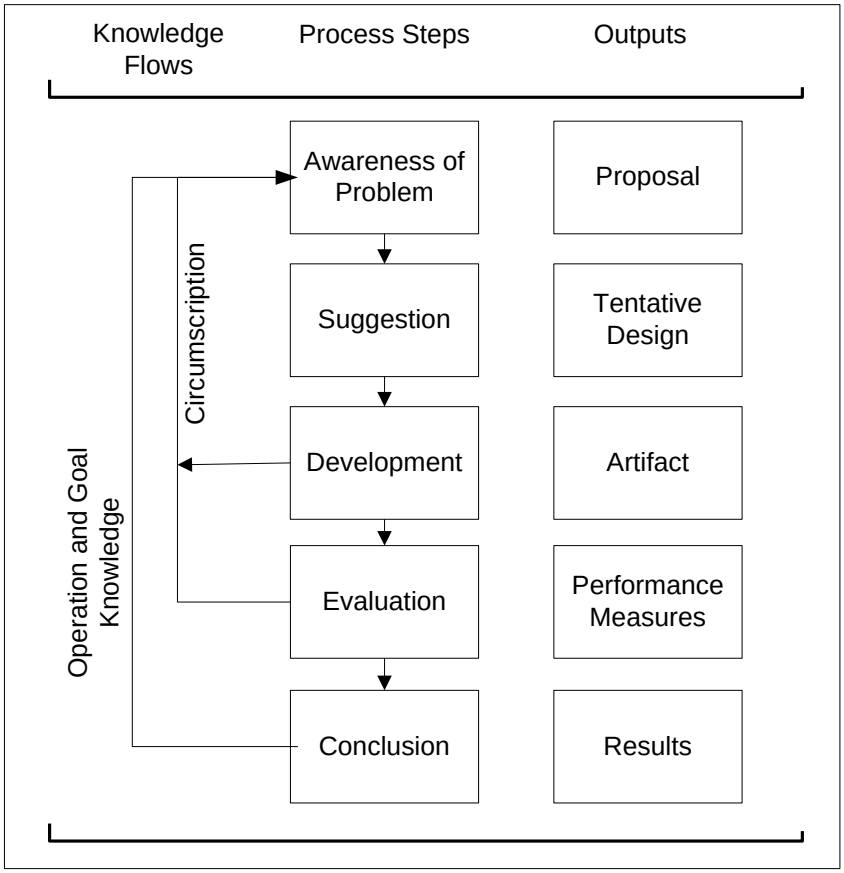

Figure 7: The general methodology of design research (Jarvinen 2007)

state of the new information system, in this case the new QMS, and technical development produces the realisation of that new system.

In design science, the two main activities are building and evaluation. It produces design knowledge in terms of concepts, constructs, models and methods. Johansson and Stenmark (2005) wrote that “research in the build activity should be judged based on value or utility to a community of users”. This evaluation activity will be evident in the case study, where the new IT-based QMS will be used by all the employees of the research partner and can be evaluated by the value and utility that they experience when using it.

ACTION RESEARCH	DESIGN SCIENCE
Action research emphasizes the utility aspect of the future system from the people's point of view	Design science's products are assessed against criteria of value or utility
Action research produces knowledge to guide practice in modification	Design science produces design knowledge (concepts, constructs, models and methods)
Action research means both action taking and evaluation	Building and evaluation are the two main activities of design science
Action research is carried out in collaboration between action researcher and the client system	Design science research is initiated by the researcher(s) interested in developing technological rules for a certain type of issue. Each individual case is primarily oriented at solving the local problem in close collaboration with the local people
Action research modifies a given reality or develops a new system	Design science solves construction problems (producing new innovations) and improvement problems (improving the performance of existing entities
The researcher intervenes in the problem setting	Design science research is initiated by the researcher(s) interested in developing technological rules for a certain type of issue. Each individual case is primarily oriented at solving the local problem in close collaboration with the local people
Knowledge is generated, used, tested and modified in the course of the action research project	Knowledge is generated, used and evaluated through the building action

Table 6: Similarities of the fundamental characteristics of action research and design science (Jarvinen, P 2007)

Based on table 6, a description of how action and design research will be used inthe thesis will be presented.

Diagnosis and Awareness of Problem

In the developing and implementation of a new intranet-based QMS at the research partner, the project will be handled as continuous iterative loop. The researcher had to diagnose the problem and find its root cause. This was done by analysing the current QMS and relevant quality documents, as well as secondary data about the standard. The current AS-IS situation was looked at to get an overview of the research partner's quality status and to find the gap (gap analysis). In this analysis phase, the current QMS was assessed against criteria of value or utility to determine what needs improvement; the action planning started at

this point. Action research will be used to analyse and develop the requirements for a quality management system that will be implemented by the organisation. The output of this phase is the proposal of what the outcome of the project will be.

Action Planning / Suggestion

When the gap analysis is done, the researcher has found the places that need to be improved and must develops a plan to correct them. The planning and action taking happen in collaboration with the client system and the researcher. At this stage, they modify the given reality and develop a new system. Design science is utilised as the research tool, because it produces design knowledge by means of concepts, models and methods. Design science helped to develop the technological requirements of an intranet-based QMS. The performance of the existing entity will be improved when design science helps to produce new innovative ways to solve the problems, whilst keeping the customers' point of view in mind. The output of this phase will be the tentative designs to achieve the proposed outcome of the project or QMS.

Action Taking / Development

When the actual new QMS is being built, the primary goal of the action taking will be to solve the local problems in close collaboration with the people involved, who will use the system in their daily activities. The action researcher intervenes in the problem setting here, because different scenarios will be designed and tested in an iterative process to find the optimal solution for most problems. The output in this phase is the developed artefact: the model or framework that will be used to achieve the proposed results when it is successfully implemented.

Evaluation

Development, evaluation and further suggestions are often iteratively performed, as in the present case. When it is seen that a model or framework fails to achieve the proposed results, the iterative process will go back to a previous step in the cycle (the awareness of the problem). The researcher must go through the cycle until he/she is satisfied with the results and the QMS is ready to be evaluated by an external certification body. If the audit from the external certification body doesn't achieve the desired results, the researcher has to deal with the non-conformances and go through the iterative process again.

Specifying learning and conclusion

After the most suitable model for the QMS was chosen and implemented, the research partner needed to have all its employees trained to use the QMS in their daily activities. The management and maintenance of the quality management system were handed over to the person responsible for handling it. He was trained to continuously evaluate and update the system as needed. The ownership of every procedure must be clear and handed over to the responsible persons for those specific tasks. The outcome of a project like this case will be successful if the research question can be answered by means of a list of generic requirements and steps that are seen as the critical success factors when implementing an AS 9100-based quality management system in an SME. To validate this method, it was compared to a project in Sweden where the researcher acted as an observer of a similar project of implementation of an AS 9100 based QMS at an SME. This validation will be described in more detail later in this chapter.

3.1.4 Data Collection Methods

According to Mouton (2008), it is customary to distinguish between primary and secondary information. Primary data is the data that has to be collected because it already exists or it should be generated as part of the research. Secondary data is data that has been collected or interpretations that are already available on a certain topic. It can be written sources (including the internet) which discuss, comment, debate and interpret primary sources of information.

The sources of primary data used in this study are the existing quality management system and quality manual of the research partner. Any relevant quality documents of the company as well as documents and records of the production process will also be used and analysed. If information is to be generated, the gathering method must be determined and a decision must be made about the accessibility of the sources of such information and their recording once it is collected.

The internal quality audit serves as a tool to generate information that is used in further steps of the design and development of an improved quality management system compliant with the most current version of AS 9100. The data collection mostly took place during work hours at the research partner's premises. Primary data was in the form of analysis of the business's existing quality documents and system as well as interviews regarding the documents, the overall work procedures, internal audits and observations of external audits, and their QMS, of leaders in the industry. The secondary data can be seen as the quality standard, AS 9100 itself, other quality standards, perspectives and literature on these standards, literature on the implementation of quality management systems, IT-based systems and supplier networks.

3.1.5 Document Review

Documents can be viewed as an information source which usually consists of public documents or private sources, such as controlled access documents. In many cases, the company's documents can be a crucial source of information because it contains important information or knowledge of the area that is being studied. An advantage of documents is that they are trustworthy and cannot be influenced by the researcher during his/her studies. Access to the documents can be yet another advantage, because researchers wouldn't need to gather all the information needed in the investigation. A disadvantage may be that, for elaborated research purposes, researchers may not find all the data that they need in the documents because it is difficult to comprehend their contents. The validity of documents can also present some problems for the researcher.

3.1.6 Interviews

With qualitative research interviews, the researchers will try understand something from various subjects' point of view and uncover the meaning of their experiences. Interviews allow people to convey to others a situation from their own perspective, using their own words. Research interviews are based on the conversations of everyday life. They are conversations with structure and purpose that are defined and controlled by the researcher. Although the research interview may not lead to objective information, it captures many of the subject's views on a particular topic. Unlike quantitative research, where the basic subject matter is object data, in this case it consists of meaningful relations that must be interpreted.

The interviews can be unstructured, semi-structured or structured. Unstructured and semi-structured interviews were conducted by the researcher throughout the thesis to prevent the respondents' answers from being artificial and not displaying the speaker's true feelings; the interview must not be structured in such a way that it controls the respondent's response.

The selection of respondents was done in accordance with the responsible persons for certain activities and also based on recommendations by the top management of the research partner (Rapoport 1970).

3.1.7 Reliability and Validity

3.1.7.1 Validity

Validity indicates how well a measuring instrument or research method really measures what it is intended to measure (Johansson, Stenmark 2005). Internal validity indicates the extent to which the results agree with other situations similar to the study, while external validity is the extent to which the solution or results of the investigation can be generalised. To achieve external validity, the internal validity needs to be high.

To ensure the internal validity of the investigation, several strategies can be used. The study was based on the latest version of the research partner in the case study's quality documents and standard requirements, which can be considered trustworthy because the documents were used in previous external audits. However, misinterpretation can still cause problems, and therefore, different people within the company with experience in the various departments of the quality system were used for confirmation or rejection of the interpretations made. In these cases, the goal was to obtain the most objective interpretation as possible. Nevertheless, the people who assisted in the interpretation of these documents could have added their own subjective thoughts on the subject.

The requirements for certain documents are sometimes not followed in practice. In these cases, an effort was made to follow the instructions in the documentary requirements and point out the differences, especially during the gap analysis and when internal audits were conducted.

The thesis is mainly interesting for the research partner, because the investigation is made against their quality management system and actions associated with it. Efforts were made to generalise the implementation of the quality standard AS 9100 for SMEs and therefore other companies in the aerospace industry may also find it helpful. The methods used, the workflow process and discussions of the topic may be useful in similar work environments where quality is reviewed to meet the common requirements for such quality management systems. The study also indicates the type of work required to adapt an IT-based quality management system to incorporate other systems and documents used in the business.

As part of the validation, the investigation was verified by testing the results obtained from the study of the research partner in Sweden on other SMEs in the aerospace industry:

3.1.7.2 Reliability

Reliability is the ability to repeat the study and obtain the same results. No random error will affect the outcome and should be the same regardless of the identity of the party who conducts the investigation (Johansson, Stenmark 2005).

Since the quality standard AS 9100 is audited with the help of a standardised checklist, AS 9101 D, there are a number of pertinent points an auditor needs to investigate, regardless of whom the auditor or certification body performing it is, provided they use the same versions of the documents. In such a case, the results should be consistent of similar. However, there is a risk that the conclusions and recommendations of the implementation depend on the individuals who are conducting the investigation and the choices they make.

4. Case Study Background:

The case study was conducted in collaboration with a research partner, Daliff Precision Engineering (Pty) Ltd. An overview of their context as manufacturing company is described. The diagnosing phase in figure 8 is explained in this chapter. For the purpose of this study, a thorough understanding of their quality management system and business processes was needed. To answer to this request, the quality manual and QMS were analysed and described. The process of analysis was documented in terms of the five main Clauses of the AS 9100 standard.

4.1 Research Partner Background: Daliff Precision Engineering (Pty) Ltd

Daliff Precision Engineering is a medium-sized company that manufactures small aerospace parts as a tier-3 supplier in the Airbus Industry supply chain; Daliff acts as the research partner. The company specialises in aerospace structural materials, such as titanium and aluminium, as well as heat resistant superalloys, such as Inconel and Kovar machining. The company has between 45 and 50 employees.

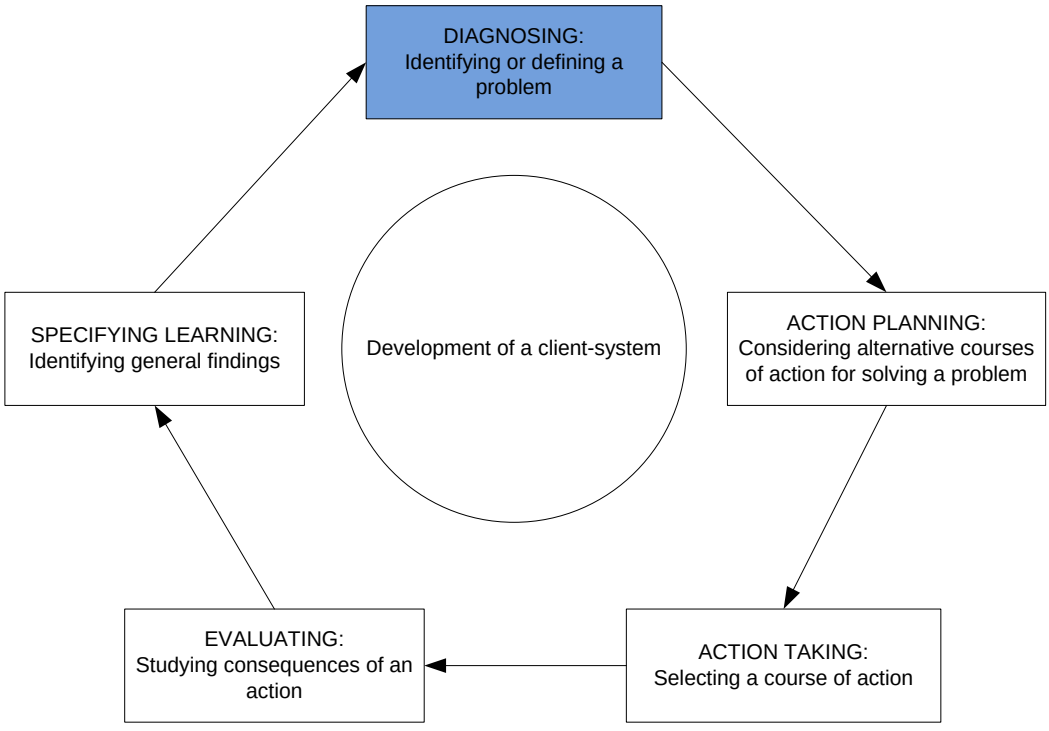

Figure 8: The cyclical process of action research (Susman 1978)

The research partner acquired AS 9100 certification in 2007 and its quality management system, which was analysed, is based on ISO 9000:1994. The standard was mainly based on quality assurance by means of preventive actions and was not focused on customer

satisfaction and process control. AS 9100 is based on ISO 9001:2000, which is generic and can be implemented in most types of business environments, because it is less biased towards the manufacturing sector. It no longer restricts organisations according to type, size or product category. ISO 9001:2000 also follows a process approach. It includes some new requirements, such as increased commitment of top management to the development and improvement of a QMS; consideration of statutory and regulatory requirements; the establishment of measurable quality objectives; the monitoring of information on customer satisfaction; and pursuing continual improvements. The company needs to understand these new requirements, and should consider addressing them in the existing system at the appropriate time.

When Daliff developed their quality management system in 2000, it was developed according to the ISO 9000:1994. The business functioned well with this quality management system, except that it later became an obsolete document that no longer reflected the correct procedures and workflow diagrams in use at that point in time. The reason for this was the difficulty to update this paper-based system and to keep track of all the changes, resulting in the updating process becoming a low priority. The revision of such a system is often time-consuming and is left until the last possible moment before it is evaluated again. This usually happens just before an audit. In the case of ISO 9000, the process of acquiring certification entails an external audit by a certification body. It is not a once-off certification that lasts indefinitely, but needs to be recertified at regular interval decided by the certification body.

After consideration of the research partner's quality management history, one will understand that, in order to adhere to the ISO 9000 requirements, the industry partner needed to analyse and rectify their management system once every 3 years. Document and process control play an extremely important role in this three-year life cycle of a QMS.

For the research partner it was easier to rectify the small changes and additions to the already existing quality management system, even when the format and focus of the standard changed to ISO 9001:2008. They still complied with the standard after additions had been made to their system, but their quality management system subsequently became a document that was used for auditing and not used regularly in their everyday production. If applied and utilised correctly, it would ensure that quality is managed well throughout the manufacturing process. The document became difficult to audit because of the format and the unstructured additions that were only filling gaps created by revised standards.

When they decided to apply for AS 9100 certification, the additions to the aerospace quality standard were made to their current system. This implied that their QMS was based on ISO 9000:1994, with additions for ISO 9001:2008, as well as those for AS 9100. It is a

system that satisfies the requirements, but it was built on a platform that was not structured correctly from the start.

To get an overview of the management of the business, the structure of the business as described in the QMS was evaluated first and changed according to the current status of their management. This method enabled the author to start analysis of the quality position of the business in a top-down approach.

The structure of the business according to their outdated quality management system is shown in figure 9.:

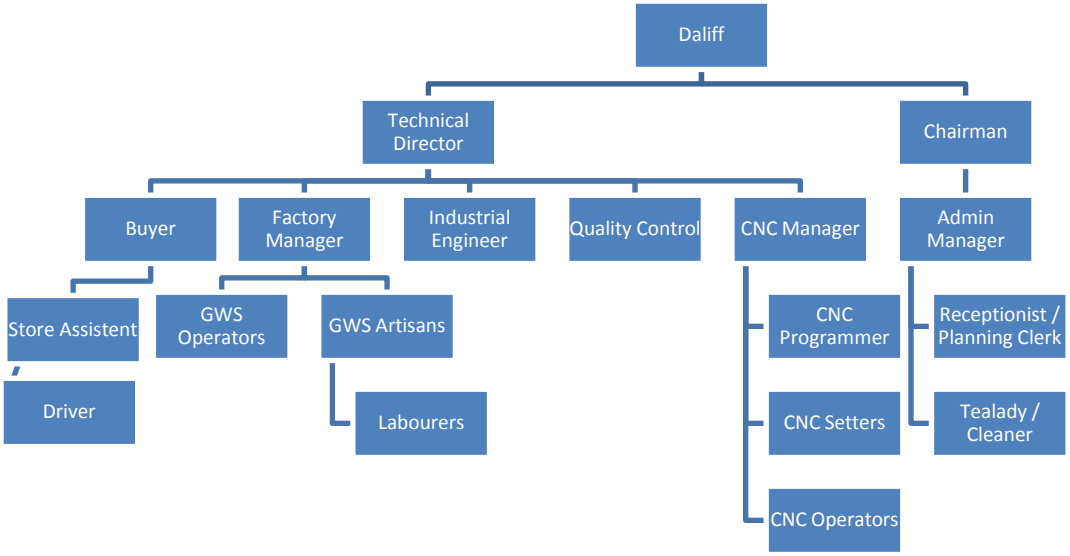

Figure 9: Previous company structure

After revisions, the structure of the company has changed to the following structure which was a true reflection of their AS-IS situation, shown in figure 10::

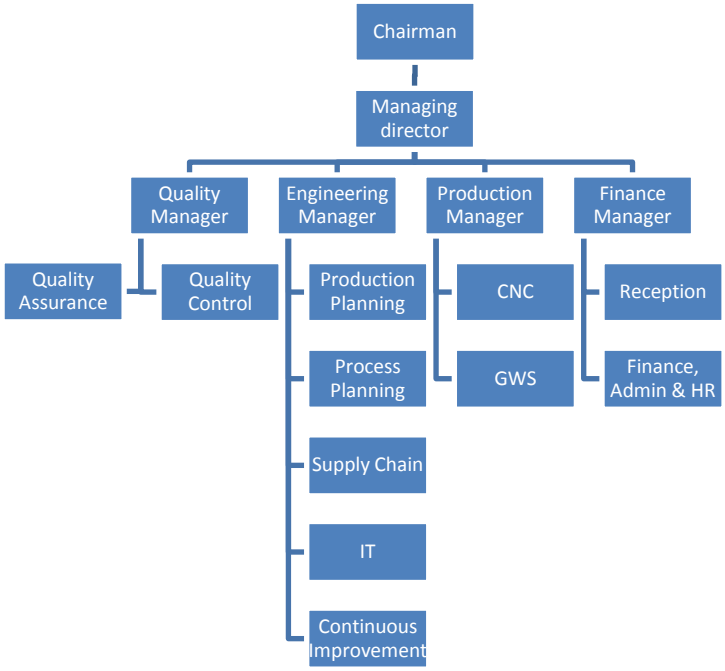

Figure 10: Current company structure

4.2 Quality manual and QMS Analysis

The objectives of the analysis of the industry partner's QMS were to:

- Familiarise itself with the company and its processes;
- Determine the AS-IS position of their quality management system's status and determine the gaps;
- Get to know AS 9100 and its critical success factors, and sorts the processes to serve as a guideline when developing the QMS procedures in the Design and Development chapter.

The quality management system of the research partner currently used was investigated to get a clear picture of the gaps. The quality documentation consisted of a quality manual and a quality management system (procedures for the processes). The quality manual is used as a guide to the quality management system procedures. In this manual, the headings of the QMS are described and it also gives an overview of how their system works as well as where to find what in the document by means of a cross-reference matrix. It is merely a descriptive document that follows the QMS wherever it is kept. If something in the QMS needs to be changed, it is easier to trace the changes in an explanatory document than to change the revision status of the QMS. A change record is kept in the quality manual that indicates the changes in the QMS.

The process that was followed in the case study is explained by means of a flow diagram described in figure 11; the first step is described in this chapter; in the following chapters the

diagram is repeated, highlighting the specific step that is discussed. (Refer to figures 15, 17, 19 and 35.

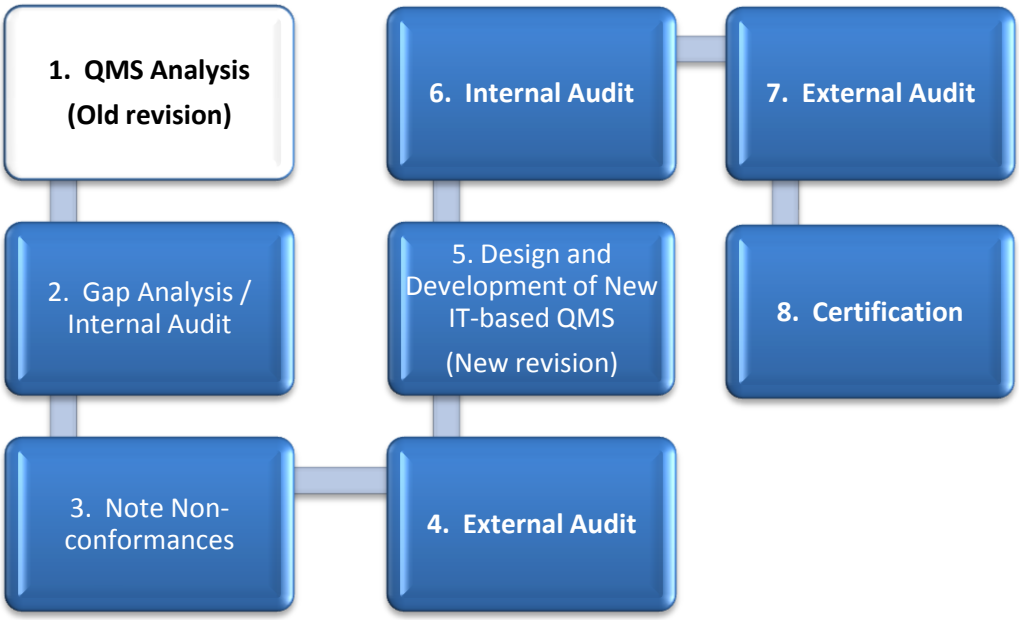

Figure 11: Description of the Case Study

4.2.1 Description of the Analysis Process:

The research partner's QMS was analysed to get a clearer picture of the business processes and procedures.

When the quality management system for a specific quality standard is planned and designed, it is important to have a very clear understanding of the quality standard and its requirements.

The AS 9100 quality standard as well as the ISO 9001:2008 can be divided into five main clauses:

- Quality Management System
- Management Responsibility
- Resource Management
- Product Realisation
- Measurement, Analysis and Improvement

These five areas will be discussed in the light of the research partner's QMS, AS 9100 and ISO 9001:2008. Primary data gathered from observation may also serve as an interpretation method of the standard.

4.2.2 Clause 4: Quality Management System

The quality manual and quality management system that were used in this analysis have been established and implemented, and are maintained in accordance with the company policy and the requirements of ISO 9001 and AS 9100. It is a guide and reference tool to using their QMS. The company's original QMS was established in July 2000, updated to comply with ISO 9001:2000 in November 2003, and has since been modified and expanded to conform to the requirements of AS 9100 revision B in December 2007. In the manual it is stated that any work undertaken prior to 2008 may not be compliant with AS 9100.

The QMS consists of a Quality Policy Statement, Objectives, Organisational Structure and Functional Responsibilities. This process-based system has been implemented and is operated by means of documented procedures, work instructions and records that relate to the company's operations. Table 7 describes the reasons for revision of the QMS and quality manual.

Table 7: Change record in the quality manual

Rev no	Date	Reason for Change	Approved
00	June 2000	Draft issue	Internally (by means of an internal audit)
01	July 2000	First official issue	Externally
02	November 2003	Change to ISO 9001:2000	Externally
03	December 2007	Compliance with and acknowledging the requirements of AS 9100 Revision B	Externally
04	December 2009	Design and Development of IT-based QMS, according to AS 9100 Revision C	Externally

Their QMS was developed and implemented to comply with the requirements of ISO 9001 and AS 9100 and to relate to the business requirements and activities of Daliff Precision Engineering (Pty) Ltd, which affect product and service quality. Product and service quality, and therefore the achievement of customer requirements, are controlled through the QMS.

The QMS is defined in a four-tiered, cross-referenced documentation system consisting of four levels, shown in figure 12:

Level 1: The Quality Policy Documentation contains the Directors Quality Policy Statement and the policy and strategy employed by the research partner to implement each of the relevant ISO 9001 and AS 9100 elements.

Level 2: The Procedures Documentation describes the activities and documentation flow, both internally and between the research partner and their customer or suppliers.

Level 3: The Works Instruction Documentation, where necessary, includes all detailed instructions used to control and define specific activities in all areas of the company.

Level 4: The documentation that is used during the procedures as part of the quality activities is described at this level. Records of all activities that relate to product quality are established and maintained as necessary.

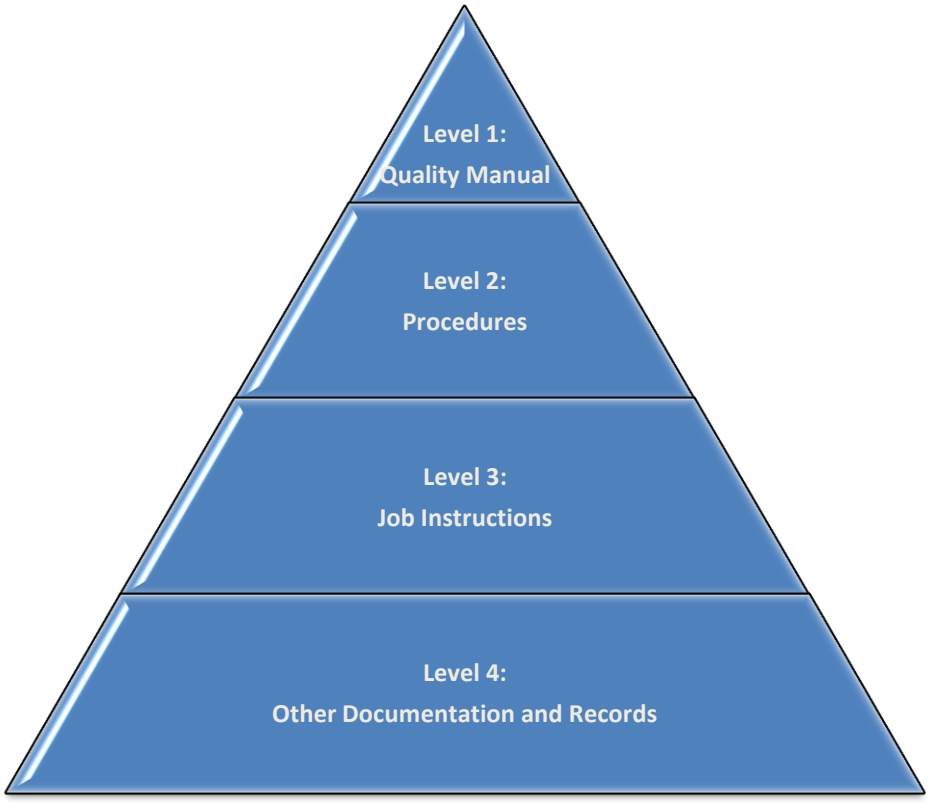

Figure 12: Typical structure of an ISO9000/AS 9100 system (Department of Trade and Industry, 2005)

4.2.2.1 Quality planning

The research partner utilises mainly Procedures and Work instructions describing specific quality practices, resources, responsibilities, and sequences of activities relevant to the particular operations performed for customers. Typical examples of what these Procedures and Work Instructions could contain are:

- Sequence of activities in the form of a flowchart
- Suitable testing, inspection, auditing and reporting frequencies
- Specifications, test methods, resources, time scales
- Allocation of responsibilities, authorities and resources

Special attention will always be given to the identification and acquisition of any resources and skills needed to ensure customer satisfaction. They also focus on ensuring compatibility between our processes and the applicable documentation. The latest technologies will be employed as applicable or as required by the customer. If any measurement requirement exceeds the known state of art, it will be handled in the required way. The research partner

also states that it will clarify that the standards they use will be acceptable, and that it will identify and prepare quality records applicable to the process.

4.2.2.2 Control Of Documents And Records

Documented procedures are established and maintained to ensure the control over all data and documents. This can include internal documentation as well as documentation received from external sources. The Management Representative is responsible for the approval and issuing of documents and records. The policy, procedures and work instructions are reviewed and approved by the Management Representative before they can be issued.

To ensure that only current issues of the documents are in use, a master copy indicating revision status should be kept up to date by the Management Representative. All other copies will be distributed or issued by the Management Representative. A list of the copies is kept and the printed copies are stamped with the words “Controlled Copy”. Records are available for review by customers and regulatory authorities in accordance with contract or regulatory requirements.

The Management Representative removes and destroys invalid or obsolete documents and data from all points of use when issuing updated copies. Where relevant, well-identified files of obsolete documents and data are kept.

All document and data changes are reviewed and approved by the Management Representative. When it is required, the document changes are coordinated with customers and regulatory requirements in accordance with contract or regulatory requirements.

4.2.2.3 Control of Quality Records

Quality records are maintained to demonstrate conformance to customer requirements, as well as the effective operation of the Quality Management System. These records include relevant quality records provided by the research partner’s subcontractors. Where there exists a contractual agreement, customers have access to relevant quality records. All these records are legible and stored in such a way that they can be easily retrieved and adequately protected.

The following policy applies to the research partner’s records:

- identification is by form number and/or name
- indexing is numerical, alphabetical or by date
- collection, distribution and responsibility are indicated in the relevant procedure

Furthermore, the top management has access to all the records and all staff has access to records pertaining to their own operational area. Customers have to obtain permission from the Management Representative to view or have access to the records.

The storage and maintenance are done in a way that prevents damage, deterioration and loss. The retention time is as described in the relevant procedures. Periodically, the responsible person will physically destroy all records past their retention times.

4.2.3 Management Responsibility

4.2.3.1 Management Representative

A management representative is the link between the operating quality management system and the company management through the management review function which will be explained in the next paragraph. The Managing Director acts as the Management Representative for the Daliff Precision Engineering Quality Management System, and has full authority and responsibility with the task to ensure that the Quality Management System is established, implemented and maintained, and the performance of the Quality Management System is regularly reviewed and used as a basis for improvement. He is also responsible for ensuring that all the requirements of the organisation in terms of policy, objectives and supporting procedures are implemented and maintained.

The Management Representative always carries full responsibility for the QMS. Certain responsibilities and authorities may be delegated to other members of the management team. The Management Representative has direct access to the highest level of management and the freedom to resolve problems, resulting in quality at any level in the company.

4.2.3.2 Management Review

In order to establish the effectiveness and suitability of the Quality Management System to satisfy the requirements of both ISO 9001 and AS 9100, as well as their own quality objectives, top management will review the system at least once every twelve months. This review will include, amongst others, customer satisfaction reviews and associated actions, corrective actions, non-conformances, internal audit results, developments in technology, product performances, trend analysis (where appropriate), adequacy of resources, as well as the objectives and commitments stated in the Quality Policy. Records of these meetings will be kept according the instructions of the control of documents procedure.

4.2.4 Resource Management

4.2.4.1 Responsibility and Authority

Responsibilities of all personnel are described in detail in the relevant procedures and work instructions. All personnel have the necessary authority to carry out their responsibilities. The network of personnel is outlined in the organisation chart authorised by the Director.

4.2.4.2 Resources

Before accepting any contract, the research partner verifies that all necessary resources, including personnel and equipment, are available or can be obtained by means of a risk analysis. Only suitable qualified personnel are assigned for the management and performance of work verification activities and the implementation, maintenance and improvement of the Quality Management System.

4.2.4.3 Training

Documented procedures detail the system to ensure that all staff is suitably trained to perform their duties. Training requirements will be identified and communicated to the Management Representative, who in turn will ensure that the necessary training are provided. Records of training will be kept. Training can be either on the basis of appropriate education, or internal and/or external training and/or experience.

4.2.5 Product Realisation

4.2.5.1 CONTRACT REVIEW

Documented procedures for all sales and related activities as well as their coordination are documented in the procedure for contract review. This includes internal and external communication channels and customer interfaces.

Before accepting a contract or order, the following are reviewed:

- all requirements are adequately defined and documented
- all differences between the tender and final contract/order are resolved
- the research partner is capable of satisfactorily fulfilling the customer's requirements and all risks are reviewed
- statutory and regulatory requirements are met whilst executing the contract

All changes to a tender or existing contract will be agreed upon. The changes will then be confirmed in writing, or the Management Representative will alter the contract as agreed. Records of all enquiries, tenders and contracts will be kept.

4.2.5.2 DESIGN CONTROL

Design and Development (§7.3 in the ISO 9001 and AS 9100 standard) is excluded from their Quality Management System, because these activities are not performed.

4.2.5.3 PURCHASING

Documented procedures are established and maintained to ensure satisfactory control over all suppliers and subcontractors providing products and services to the research partner. Stock material will not be purchased or used for jobs with contractual aerospace requirements. All suppliers and subcontractors are evaluated and selected based on their ability to provide the products and services required. The Management Representative has the responsibility and authority to make decisions in this regard. The selection of suppliers and subcontractors are discussed with their customers and an approved suppliers list is kept.

All purchasing documents are reviewed and authorised by the Management Representative. In case the customer requires verification of the supplier/subcontractors activities at their premises, this will be specified in the purchasing agreement. The research partner is responsible for the quality of all products purchased from suppliers, including customer designated sources.

No aerospace work is currently subcontracted by the research partner.

4.2.5.4 CONTROL OF CUSTOMER-SUPPLIED PRODUCT

Customer-supplied products, which can be material, documents, information, data, or equipment, are always treated with the greatest care and confidentiality.

A customer-supplied product is:

- Checked before processing to ensure suitability for further processing
- Handled and stored in a manner that prevents damage and deterioration

The customer is informed immediately if:

- Any product, upon receipt, is found to be unsuitable for processing
- Any product is lost or damaged
- A product is found to be incompatible with the process

Any lost, damaged or otherwise unsuitable rendered item is reported to the customer as soon as practically possible.

4.2.5.5 PRODUCT IDENTIFICATION AND TRACEABILITY

Allocating a unique job number when any order is placed ensures Product Identification and Traceability. This job number accompanies all materials, intermediates and the final product during all stages of production and delivery. The purchase order number will accompany all stock material. Records are kept for the period specified in the contract..

4.2.5.6 PROCESS CONTROL

In order to ensure that all processing activities take place under controlled conditions, the following steps have been implemented:

- the provision and maintenance of a suitable working area, associated utilities and supporting services
- documented instructions, defining the manner of production, are available at the workplace, where the absence of such instructions could adversely affect quality
- the provision and use of suitable process equipment (both hardware and software) and the correct environment
- controls to ensure that compliance with the relevant drawings, specifications and procedures/work instructions is achieved
- suitable process parameters and product characteristics are monitored and controlled
- workmanship criteria are clearly specified
- all equipment is included in a maintenance schedule

Records are kept in accordance with the requirements outlined in the various procedures. Should qualification of processes, equipment and personnel be required, it will be agreed in advance and specified in the order.

4.2.6 Measurement, Analysis and Improvement

4.2.6.1 INTERNAL QUALITY AUDITS

Documented procedures are in use to verify, on a regular basis, whether quality activities and related results comply with the documented Quality Management System, as well as to determine the effectiveness of this system. All elements of the Quality Management System are audited at least every twelve months, in accordance with the internal audit schedule. Internal audits will be coordinated by the Management Representative, and carried out by personnel independent of those having direct responsibility for the area being audited. All findings will be recorded on an Audit Findings Report, and are discussed with the audited company, who will sign for witnessing the findings. The Management Representative will make sure that the necessary corrective actions are effectively implemented and will keep the records. The results of these internal audits will be presented at the Management

Review Meeting.

4.2.6.2 INSPECTION AND TESTING

Documented procedures for inspection and testing are established to ensure that the customers' specified requirements are met. These requirements are transmitted via the Job Card, and verified as indicated in the document. No incoming material is used, unless it is verified that it complies with requirements.

The nature of this verification is determined by the amount of control exercised by the supplier (supported by recorded evidence) and can be via Certificates of Analysis and/or Compliance or by carrying out visual inspection. The level of inspection is selected so as to balance the costs of inspection against the consequences of inadequate inspection.

Documented procedures ensure that products are inspected and tested at appropriate points in the process to verify their conformity. The location and frequency depends on the importance of the characteristics as well as the ease of the verification.

No products are released for further processing until they have been verified, except under positive recall procedures. In the use of sampling inspection plans, the plan must be submitted for customer approval if required.

Inspection of final products is enforced via documented procedures, which also ensure that all specified inspections and tests have been carried out, so as to provide evidence that the customer's requirements have been met.

No products are dispatched or handed over to the customer until such time that all the specified inspections and/or tests have been satisfactorily completed, recorded and authorised.

Records of the above activities provide evidence that the products have:

- been inspected;
- passed or failed; and
- been released by an identified and traceable inspection authority.

Records are kept as outlined in the relevant procedures.

4.2.6.3 CONTROL OF INSPECTION, MEASURING AND TEST EQUIPMENT

Documented instructions are available and implemented to ensure that all inspection, measuring and test equipment is controlled, calibrated and maintained. All this equipment is used in such a way that measurement uncertainty is known, and is consistent with the

required measurement capability. Customers can be provided with relevant calibration data upon request.

The research partner ensures that:

- all equipment is capable of providing the required/specified accuracy and precision
- all equipment is calibrated, at prescribed intervals, or prior to use, according to recognised standards/procedures
- the calibration process is clearly defined
- the calibration status of all equipment is clearly indicated by suitable means
- calibration records are maintained
- previous results are validated (where practical) when equipment is found to be out of calibration
- environmental conditions are suitable for the calibrations, inspections, measurements and tests performed
- equipment will be treated in such a way that accuracy and fitness for use are maintained
- equipment is safeguarded from unauthorised adjustments that would invalidate the calibration settings

4.2.6.4 INSPECTION AND TEST STATUS

The inspection and test status of the products during the various stages of production will be indicated by suitable means as indicated in the various relevant procedures.

This ensures that no product is released unless it has passed the required inspections and tests, unless it is released under a properly authorised Concession.

4.2.6.5 CONTROL OF NON-CONFORMING PRODUCT

Documented procedures and instructions are in use to ensure early detection of non-conforming products, thus preventing the unintended use of such products. Whenever such products are encountered, they are identified, documented, evaluated, segregated disposed of, and the relevant functions are informed. This can take place during the manufacturing process, at the inspection stage, during transport and even during use by the customer.

Documented procedures, clearly defining responsibilities and authorities, are in use to dispose of non-conforming products. This disposal can be:

- reworked to meet agreed requirements;
- accepted by concession (with or without repair);
- regarded for alternative applications; or

- rejected and scrapped.

In the event where a product does not meet the specified requirements, a concession for use can be requested from the customer. If this is the case, proper records that record the accepted non-conformity and repairs, as well as their acceptance, will be kept.

Whenever products are repaired or reworked, they will be re-inspected in accordance with documented procedures.

4.2.6.6 CORRECTIVE AND PREVENTIVE ACTION

Documented procedures are implemented to ensure that corrective and preventive action is taken to remove the root cause of actual or potential non-conformities. The degree of the actions will depend on the risks encountered, as well as the magnitude of the problems. If required, documented procedures will be updated as a result of corrective and/or preventive action.

4.2.6.6.1 Corrective Action

Customer complaints and non-conformances are treated with the utmost importance, and are always reported to the Management Representative as soon as possible. Procedures are in place to ensure effective handling. Investigations into the root cause of the problems will be formally recorded.

Corrective action will be determined to ensure the elimination of the root cause of the problem. In the case that the supplier is responsible for the root cause of the problem, the corrective action will flow down to the supplier. Controls are implemented to ensure that corrective action is taken effectively.

4.2.6.6.2 Preventive action

Scrutiny of audit reports, quality records, non-conformance reports, customer complaints, liaison with customers, etc., will expose potential causes for non-conforming situations, processes and work operations.

In case a potential non-conforming situation is detected, the Management Representative is informed as soon as practical. The Management Representative will then determine the necessary steps to deal with the situation, initiate preventive action, and apply controls to ensure suitability of the preventive action. The Management Representative will ensure that proper records are kept for submission to the Management Review Meeting.

5. Gap Analysis and Audit Methodology:

Planning for AS 9100 certification includes an internal audit which points out the shortcomings and non-conformances that the business still has, before it can comply with the standard. Internal audits are called “first-party auditing” and are required by the AS 9100 Standard (Section 8.2.2). This chapter will describe the general requirements and guidelines to perform an internal audit. The process of conducting the internal audit at the research partner is explained with special reference to the handling of non-conformances and findings. The external audit conducted by a certification body (CB) was observed and the results used for further investigation into the design and construction phase of the project. This is the Action Planning step of the action research process in figure 13. The non-conformances found in the audits require a root-cause analysis as well as corrective and preventive actions to solve them.

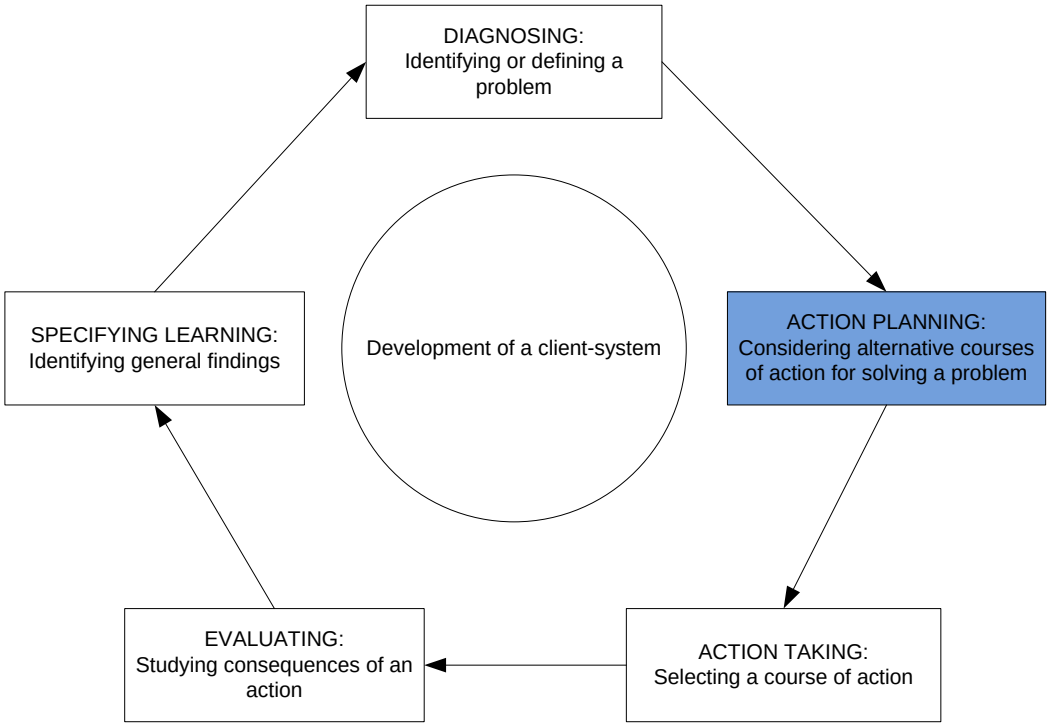

Figure 13: The cyclical process of action research (Susman 1978)

5.1 Background to Auditing

According to Collins and Steiger (2009), an internal audit is a tool that assists in determining whether the quality activities meet the requirements and demonstrates the effectiveness of a quality management system as well as ensuring the continued capability of all business management system processes. This tool also helps to discover weaknesses prior to any negative effect on the product and thus minimises the occurrence of non-conformances.

The internal audit is the evidence of compliance to a relevant quality standard. Internal auditors within the organisation must be selected, trained, evaluated, approved and continuously re-evaluated. Internal auditing is a requirement of the AS 9100 Standard and the process can be used when performing the gap analysis as well as regular internal audits. The Internal Audit is part of the measurement, analysis and improvement requirements. The Standard gives clear requirements that the organisation will conduct internal audits at planned intervals. Records of these planned intervals and the results of the audits will be kept for scrutiny and used to continually improve the quality results. These audits will verify the status of conformity to the quality management system requirements determined by the organisation. They also ensure that effective corrective action is planned and implemented. Records will be kept to monitor the effectiveness of the action.

The non-conformances that are found are a reflection of the position of a business's quality status at that stage. The non-conformances can also be seen as the gap that needs to be filled in order to comply with a certain standard.

An audit or gap analysis has the purpose of pointing out the conformity or compliance of a system. When deviations from the system are pointed out by this analysis, management needs to deal with the non-conformances in an appropriate way to ensure ongoing compliance and conformance and, as mentioned earlier, prevent the non-conformance from reoccurring. This appropriate way of ensuring compliance and conformance will be discussed with due consideration given to literature on this subject. The way in which internal audits are conducted is investigated to determine whether this literature can be used and applied in a general way.

According to Russell (2005), an audit is an extremely useful tool for management to acquire unbiased evidence about the true status of the business's quality position.

Auditing as a tool is used to: (Russell 2005)

- Provide input for management decisions, to prevent unnecessary costs and rectify problems;
- Alert management of actual or potential risks;

- Identify areas of opportunity for continual improvement;
- Assess personnel training effectiveness and equipment capability;
- Provide visible management support of the quality, environment, and safety programmes;
- Ensure ongoing compliance and conformity to regulations and standards;
- Determine system and process effectiveness;
- Identify system and process inefficiencies.

There are two basic approaches available to auditors: vertical auditing and horizontal auditing. Vertical audits are in-depth audits that focus on a specific function or department only; they only determine the effectiveness and conformity of that specific function to monitor the use of relevant procedures as support functions. Internal audits can be categorised as vertical audits.

An external audit will usually be a horizontal audit: it traces a process from the beginning of the cycle until the very end. It focuses on the procedures' support of the process itself and may cover many different functions or departments. It is the responsibility of the quality manager to select, train and manage the internal auditors (The National Computing Centre 1996).

Auditors must be independent of the department which they will audit. This prevents conflict of interest and company politics to intervene in the results and findings of the internal audit and helps to achieve an unbiased assessment of practice (The National Computing Centre 1996).

5.2 Conducting an Internal Audit

When conducting an internal audit, it is of high importance to be evaluated against an objective reference base such as the relevant quality standard (in this case, AS 9100) and the documented quality management system.

The framework of such an audit cycle will typically include a planning phase in which the status and importance of areas to be audited and previous results are considered. All the preparation will be done to familiarise oneself with the environment of the function to be audited as well as determine the scope of the audit. For the purpose of this study, the author conducted the internal audits because there was no conflict of interest and it was part of the action research purpose to be an active part of the investigation and solution.

A checklist of the relevant questions to the function is also prepared in this cycle before the function is audited. The auditee may look at the audit checklist beforehand to get a clearer

picture of the scope and what will be expected of him. The audit will start with an opening meeting in which the scope of the audit is clearly explained and any uncertainties about the checklist or other questions are clarified.

Where non-conformances are identified during an internal audit, it should cross-referenced to the company QMS and AS 9100 or only AS 9100. A closing meeting will be held after the internal audit has been executed and the non-conformances will be discussed and where applicable the corrective actions will be decided upon. The dates by which this corrective action should be implemented should also be determined and completed. An audit report will be compiled, which will include all the non-conformances and their corrective actions, as well as completion dates. The audit is only considered closed once the corrective actions have been implemented and confirmed by the auditor (The National Computing Centre 1996).

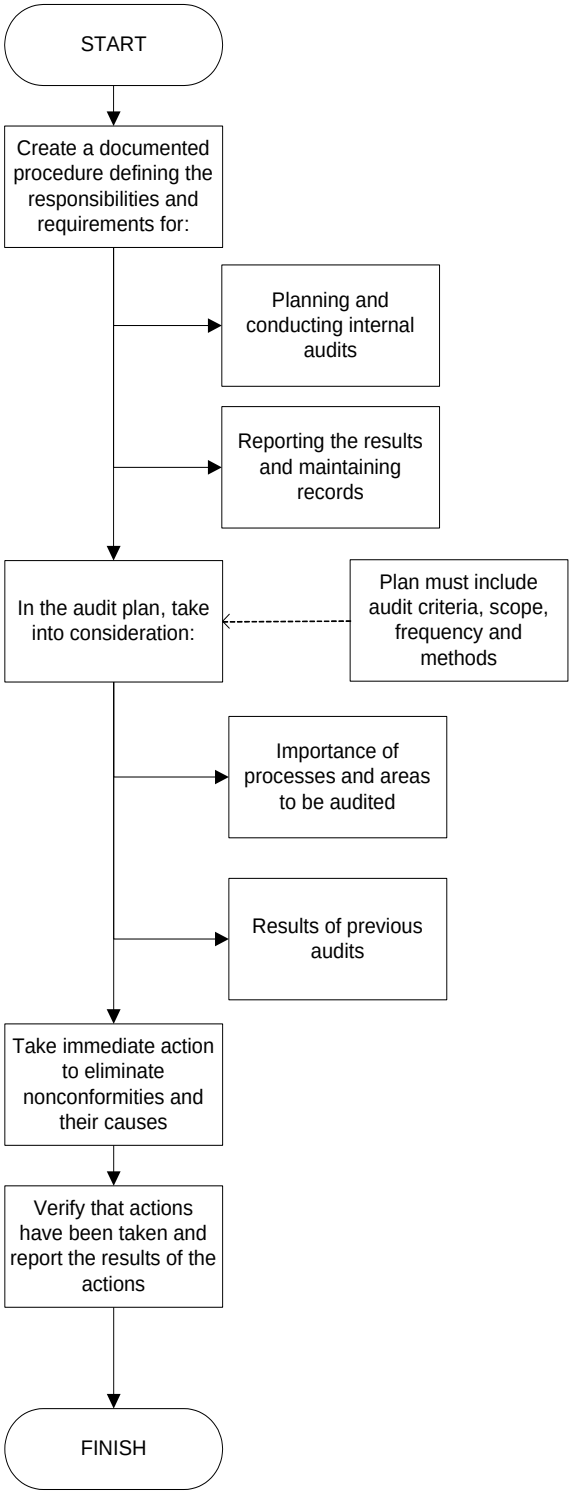

Figure 14: Guidelines to design and develop an internal audit (Myhrberg,E.V. 2006)

Advantages of internal audits are that they may point out trends and verify improvements; they can also serve as an indication of the need for more technical training, or training in the utilisation of the procedures and activities.

Guidelines to design and development of an internal audit: Figure 14 served as a guideline to draw up the internal audit plan.

The research partner's internal audit plan has been planned and drawn up. It has been found that the records of the previous internal audits are kept in the way described by the procedure for control of records and that all the non-conformances of the previous internal audits have been dealt with and were closed in the proposed manner. The responsibilities of the personnel actively involved in conducting of the internal audit are described in Figure 14.

Management Representative

- Schedules audit at regular intervals and keeps records of these audits
- Identifies responsible auditors for relevant areas
- Informs company of audit date
- Discusses relevant documents and procedures with auditors

Internal Auditor

- Someone who is independent of the function he audits
- Must have a good understanding of the company's QMS
- Must have basic training in auditing techniques (arranged by the quality department and documented in the training records)

Management Representative

- Ensures that the internal auditor undergoes basic auditing course
- Ensures an audit on all elements of Quality Management system
- Discusses goals and scope of audit with company

Management Representative

- Compiles audit report
- Keeps report for records
- Makes sure that record of internal audit training is kept
- Defines the scope of the internal audit

After the business's quality manual and QMS had been analysed and explained in the previous chapter, the author conducted the internal audits of the research partner to identify the gaps that the industrial partner still had before the design and development of a new IT-based QMS according to AS 9100 Revision C could start. All the departments were audited. Internal audits were conducted by the author who had an independent view and is not involved with any of the departments. Usually, the audits will be conducted by personnel independent of the departments; they will be assigned by the Management Representative or the Quality Manager.

In order to achieve a higher competitiveness level, the organisation has to be able to identify the current quality performance and realign its strategies, operations and process to improve the quality performance. Internal audits are only one of the tools that were found to be used to determine the current quality performance by identifying the improvement opportunities and the actions to achieve them (Ramly, Ramly,E.S., Yusof,S.M. 2008).

5.3 The First Internal Audit

5.3.1 General

The first internal audit was done after the author had analysed the current QMS and was familiar with the processes of the business. All the procedures are to be checked against the Standard (AS 9100 Rev B) as well as whether the actual work procedures are carried out in practice. In this specific study, the procedures were only tested against the actual work procedures that were carried out, because the QMS had already been approved and certified as conforming to the standard in the business's certification audit in 2008.

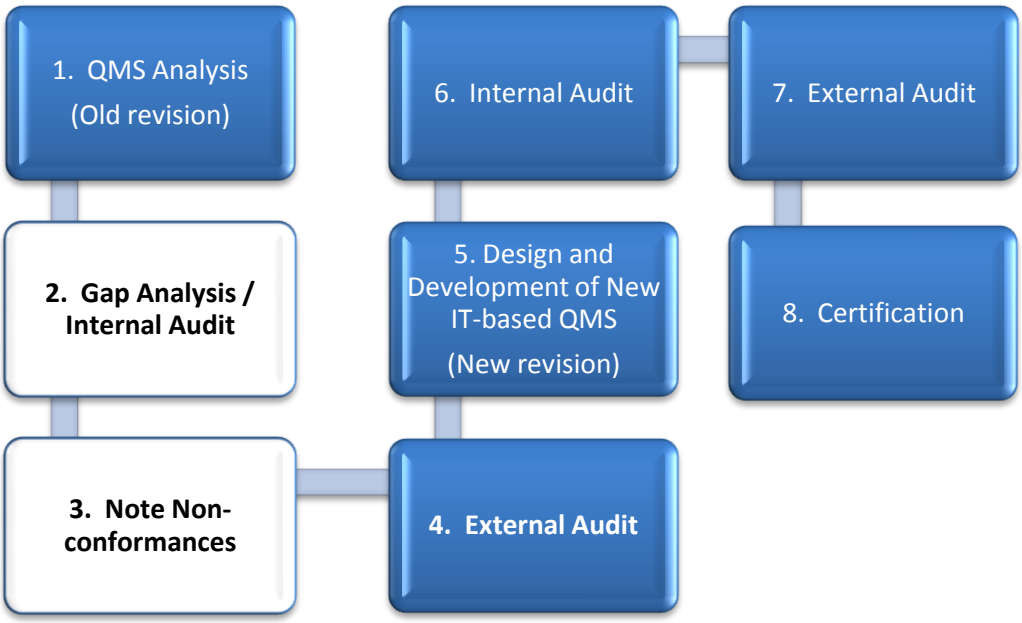

Figure 15: Steps of the Case Study

The following list of documented procedures was reviewed (the audit programme is included in the Appendix):

1. Management Review
2. Contract Review
3. Control of Records, Documents and Soft Stamps (including Configuration Management)
4. Purchasing
5. Control of Customer Supplied Product
6. Process Control (including Configuration Management)
7. Inspection and Testing
8. Control of Inspection, Measuring and Test Equipment
9. Inspection and Test Status

10. Control of non-conforming Product
11. Corrective and Preventive Action
12. Handling, Storage, Packaging, Preservation and Delivery
13. Internal Quality Audits
14. Training

Every procedure consists of a purpose, scope, reference documentation, definitions, responsibilities, records that need to be kept, reason for change, as well as activities carried out.

The audit was conducted in the following way: The auditor (in this case, the author) had studied the procedure as it is documented and then looked at the clauses in the AS 9100 standard that the procedure referenced. After the procedure was found sufficient, the author started with the audit of the actual activity to find out whether the documented procedure correlated with the actual activity in practice. A reference list of the procedures and the clauses covered by them is presented in Appendix C.

5.3.2 Conducting the Internal Audit

1. Management Review (Auditee: Management Representative)

The Management Review process (requirements) is captured in Clause 5.6. The scope of this procedure includes scheduling, planning, conducting, reporting and follow-up on all the Management Review activities which are performed. The management review process covers the whole standard. Records of this information are kept and analysed, and can be used to determine customer satisfaction.

The inputs for this functional area are the Corporate Policy, Customer Requirements, Regulatory Requirements, Planning, Resources, Data Analysis, Monitoring, Measurement and Management Reviews. The research partner states that it has a management review meeting every twelve months; minutes of these meetings are kept and they were used as the objective evidence of conforming to the Standard. The minutes were reviewed and found to address the requirements of Clause 5.6.2. An example of the contents of management review meeting minutes can be found the Appendix C.

Non-conformances and Recommendations

The non-conformances that were identified in this phase were not major. The findings demonstrate improvement possibilities. A specific non-conformance that was identified was that no minutes are taken of daily planning meetings, resulting in a complete lack of evidence of the matters handled there. Keeping minutes will help the business to notice trends and

determine where the training needs are. A further non/conformance is that the quality meetings and management review meetings minutes do not assign a responsible person or target date to the actions that need to be taken. Addition of these details will improve the control over the completion statuses tremendously.

2. Contract Review (Auditee: Management Representative)

The purpose of this procedure is to ensure that the orders, contracts and their amendments are handled according to the requirements of the Standard as well as the quality policy and objectives of the research partner. The applicable clauses are Clauses 5.2, 7.2.1, 7.2.2 and 7.2.3.

The inputs for this function include quotes that are submitted, sales orders and contracts.

Non-conformances and Recommendations

Deviations from the flow charts in the procedure were identified and the procedures were updated. Causes of these deviations are the technology improvements as well as the organisational structure changes. The persons responsible for certain actions were replaced and the processes showed improvement since the previous audit.

3. Control of Records, Documents and Soft Stamps (Auditee: Management Representative)

This procedure ensures that all the document, records and soft stamps that are controlled by the quality management system are handled correctly according to the Standard. The relevant clauses are Clauses 4.2.3, 4.2.4, 4.3 and 7.5.3.

The inputs for this procedure are all the documents and records that are in use, as well as soft stamps and the employees' passwords. A soft stamp is as legal as affixing a signature to a document. The documented processes for the control of documents, control of records and control of soft stamps (requirements for acceptance authority media) were audited against their validity, if compared to what they do in practice. The configuration management of all the documents, records and revisions is also included in this audit.

Non-conformances and Recommendations

Records of electronic data have become so important that they are no longer backed up only once a week, but once a day. The list of stamps that are used should be updated more often to ensure traceability and to have responsibility assigned to a job. If a problem keeps occurring, a trend may be picked up and training of employees may help to prevent reoccurrence. These findings were updated in the procedure.

The procedure for control of records has been documented and implemented. The proof that it is maintained and continually improved can be enhanced. The QMS is only used in hard-copy form. This makes it difficult to implement any changes and improvements. The processes that are needed for the QMS and their application are documented as procedures by means of flow diagrams and descriptions about their sequence and interaction.

The visual management of the quality management can be improved, as well as user friendliness. The document is not very audit-friendly and the personnel of the business is not familiar with the use of the document because of its static state as hard copies in allocated offices.

4. Purchasing (Auditee: Buyer)

The purpose of the procedure is to provide work instructions and describe the process for the purchase of materials, products and services, which will ensure that the activities and documentation conform to the requirements of the Standard and the quality policy of the research partner. It includes the purchasing of all materials, services and products from subcontractors and equipment such as tooling and machines that have a direct effect on the quality of the final product that the research partner sells. Clauses 7.4.1, 7.4.2 and 7.4.3 are applicable here.

The input for this procedure is the evaluation of suppliers and subcontractors, how the material certificates are verified, as well as the purchasing process and data. The research partner doesn't purchase stock material, because the material for their jobs is ordered just in time (JIT) or consists of customer-supplied materials.

Non-conformances and Recommendations

It was found that the Management Representative has delegated some authority to evaluate the suppliers and subcontractors. This has been done verbally and had to be rectified in documentation. The Management Representative wrote a letter with the scope of the Buyer's responsibility concerning this matter, which was signed and filed in the personnel records.

5. Control of Customer Supplied Products (Auditee: Buyer)

As mentioned in the purchasing procedure, the research partner manufactures parts from customer-supplied materials or products, except when stated otherwise. This procedure ensures that this process for control over the customer-supplied products complies with the Standard and quality policy's requirements. It includes all the products that are provided by customers to contribute to the final deliverable product (Clause 7.5.4).

Non-conformances and Recommendations

The procedure was found to be in order, but can be improved if the activities with the responsible persons are documented in the form of a flow diagram. This will make it user-friendly and describe the flow of work in a logical way.

6. Process Control including Configuration Management (Auditee: Production Manager)

This procedure includes all the production processes and ensures compliance with the Standard and quality policy and objectives. The processes include control of documentation for drawings and customer supplied production, machine manuals, stock parts, off-cut material as well as tooling and fixtures. It also includes planning and prioritising of the orders (risk management and scheduling) and changes to production documentation and processes. The main manufacturing processes are described with flow charts; these include the general workshop and the CNC workshop.

Non-conformances and Recommendations

The main business of the research partner has not changed since the last revision of the QMS and the process control procedures. The revisions of the Standards on which the processes were based have changed as well as the business structure. These slight changes have the effect on the QMS that there are small deviations from the work flow diagrams and the responsible personnel, which have to be rectified when the new system is built.

7. Inspection and Testing (Auditee: Quality Manager)

All incoming material, ‘First Offs’, First Article inspection, intermediates and final products are part of this procedure. It ensures that the handling of work procedures and their record keeping meet the requirements and standards of the AS 9100 as well as the quality objectives and policy of the research partner. The clauses applicable are Clauses 4.3, 7.1, 7.5.1, 7.5.2, 7.5.3, 7.4.3, 8.2.3 and 8.2.4.

Non-conformances and Recommendations

This procedure was found to be in order with slight deviations to the work flow diagram also due to the revision change of the Standards. This was rectified in the new QMS.

8. Control of Inspection, Measuring and Test Equipment (Auditee: Quality Manager)

All the inspection, measuring and testing equipment that are utilised by the research partner should be controlled according to the Standard as well as their quality policy and objectives. In this procedure, calibration of the equipment is the main activity that needs to be controlled and monitored. Clause 7.6 is applicable to this procedure.

Non-conformances and Recommendations

Some of the calibration tools were out of calibration date and this had to be corrected. The tools were placed under quarantine until they were calibrated in the next calibration audit.

9. Inspection and Test Status (Auditee: Quality Manager)

Traceability is such of high importance that the research partner has seen the necessity to have a procedure that ensures that incoming material, intermediates and final products are identified such that their inspection status is always traceable and visible. Only material or products that have passed the required inspection and tests are used or dispatched. If at any stage in the production cycle a product or piece of material is found that cannot be traced, it will immediately be reported and placed under quarantine until further notice. The applicable clauses are 4.2.4, 7.4.3 and 8.2.4.

Non-conformances and Recommendations

This procedure is in order.

10. Control of non-conforming Product (Auditee: Quality Manager and Management Representative)

The non-conforming products need to be traceable. Parts that are manufactured from customer-supplied material need to be marked and included in the batch that will be sent to the customer. The research partner does not keep stock material for aerospace jobs and this procedure is in place to prevent an artisan from disguising any mistakes by replacing it with a part manufactured from any other material than the material issued for that specific job. If this happens, it will most probably have numerous destructive effects, which may lead to fatal accidents or placing the business in danger of losing clients. The clause applicable is Clause 8.3.

Non-conformances and Recommendations

The quarantine store list needs to be updated and the non-conforming products must be dealt with before the external audit. A responsible person has been assigned for this task and a date for completion has been selected.

11. Corrective and Preventive Action (Auditee: Management Representative)

Customer satisfaction is the main objective of the business. This procedure ensures that customer complaints as well as corrective and preventive actions are adequately addressed according to the Standard. This procedure addresses the actions that do not satisfy the requirements of the customer. A non-conformance/customer complaint form needs to be filled out in such a case. On this form, the investigation will be filled out by means of a root cause analysis, the proposed corrective action, as well as the action that will prevent it from reoccurring. This form will be kept as proof that the matter was dealt with. The clauses applicable to this procedure are Clauses 8.5.1, 8.5.2 and 8.5.3.

Non-conformances and Recommendations

The procedure is in order, but the root-cause analysis may be improved upon in the future.

12. Handling, Storage, Packaging, Preservation and Delivery (Auditee: Buyer or Storeman)

Certain customers have specified requirements on how the final product will be packaged, preserved or delivered. These requirements, as well as the storage and handling of the material or products in process, are taken into account in this procedure. The applicable clause is 7.5.5.

Non-conformances and Recommendations

When products are packed for delivery, the storeman must make sure to adhere to all the customer requirements.

13. Internal Quality Audits (Auditee: Quality Manager)

The procedure for internal audits must be compliant with the Standard. Clause 8.2.2 describes the requirements for this procedure.

Non-conformances and Recommendations

This procedure was refined when the new QMS is built.

14. Training (Auditee: Production Manager)

Training is a necessity for the employees of the research partner in order to become and remain a world-class manufacturer. The training will take place according to the requirements of the Standard with specific reference to Clauses 6.2.1 and 6.2.2.

Non-conformances and Recommendations

The competency matrix needs to be updated. Where training is done, it needs to be documented and training on the job also needs to be evaluated and acknowledged on the matrix.

5.3.3 Internal Audit Records:

5.3.3.1 HANDLING OF NON-CONFORMANCES/FINDINGS:

After the internal audit, the findings were documented on the Non-conformance Report with dates on which it had to be closed. An example of the Non-conformance report is attached in the Appendix. All the non-conformances were filled out on the form in detail and, where applicable with reference to the clause in the AS 9100 Standard, numbered and dealt with. When constructing the new QMS, these non-conformances' corrective and preventive actions will also be taken into account.

The auditees will implement corrective actions after liaison with the Management Representative and then sign off on the Audit Findings Report after corrective actions have been implemented and handed to the Management Representative, who will then discuss the audit report at the scheduled Management Review Meeting. If necessary, follow-up audits will be arranged.

5.3.3.2 CONCLUSION TO THE INTERNAL AUDIT

The first internal audit can be seen more as an audit to determine whether the documented procedures at this stage were a true reflection of the actual processes performed by the research partner in practice. Is 'what' they do the same as what they 'say' they do?

5.4 External Audit

5.4.1 General

After the completion of the internal audits, the following checklist in table 8, can be a useful gauge to determine the company's readiness to apply for registration.

Table 8: Checklist according to The Memory Jogger 9001:2008 for Registration Audit Preparation (Collins, Steiger 2009)

Quality Manual	• Is it complete? • Does it contain all elements that you want to be registered? • Which standards are being used?
Application for Registration	• Have you selected your registrar? • Have you completed the application for registration and assesment? • Does the company provide the longterm relationship you are seeking?
Internal Audits	• Have you reviewed all recent (last two years) internal audits to ensure that all items are closed? • Were there any systems issues that should be re-reviewed at this time?
Audit Agenda	• Has this been finalised? Are all areas that you consider important scheduled to be assessed (so you get the most out of the assessment)?
Procedures	• Are all standard operation procedures current with the quality manual policies and requirements? • Do procedures in all areas correspond to the current revision status? Is the control of procedure revisions well understood by all personnel (and adhered to)?
Training	• Do all employees understand the quality policy and objectives for quality? Do they understand the quality manual and systems that affect them? • Are all records for this training current? • Have all senior managers and line personnel from areas to be visited been briefed on the assessment?
Procedural Documentation	• Are there documentation in all areas of the assessment? • Are the records complete and up to date? Do they reflect the procedureal requirements that created them?
Assessment Documentation	• Has an assessment coordinator been appointed? • Will someone be available to take complete notes during the assessment?
Daily Briefings	• Have arrangements been made for daily debriefings of each day's assessment activities? (This is an opportunity to take immediate corrective action on minor observations.)

The better the organisation is prepared, the less difficulties and gaps will be stumbled upon before certification can be achieved. The next step is to start with the application process; the Figure 16 is a flow diagram which illustrates the flow of steps in this process:

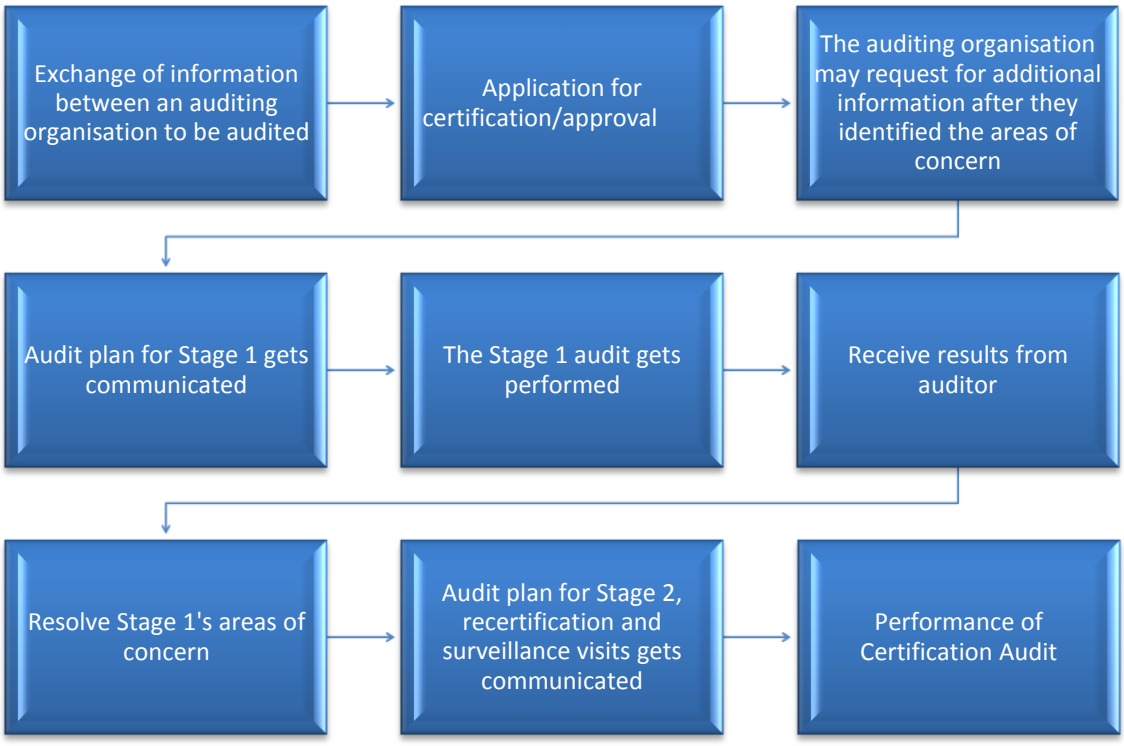

Figure 16: External Audit Process (ASE International Group, AS9101D 2010)

When a client or customer ensures your compliance to the Standard, it is called a "second-party audit". After the company has performed the internal audit, is satisfied with the results, and has dealt with all the non-conformances, a "third-party audit" will be done by a registrar body that sends one or more auditors to confirm your compliance to the Standard. After the audit results show that your company fulfils the requirements of the Standard, it receives certification by means of a certificate that is evidence of the satisfactory results.

An external audit can be called effective if it produces the intended result. The intended result of an external certification audit is the client's pleasure with the results and the organisation's ability to improve its performance. The clients in this case are the second-tier manufacturers to whom the research partner supplies small parts and the organisation is the research partner. The previous external audit report also contributed to the improvement of the performance of the organisation (Ramly, Ramly,E.S., Yusof,S.M. 2008).

5.4.2 Observation of External Audit at the Research Partner:

The external audit has been conducted by an external auditor at a Certification Body in South Africa. The author was only an observer of this step and did not actively participate in the audit procedures. The functional areas that needed to be audited were determined by the CB. The Audit Summary Report was used in the development of a reference table which will serve as a guideline during the development of a QMS, to check whether all the AS 9100 clauses are addressed, and to which procedures they refer. See Appendix A.

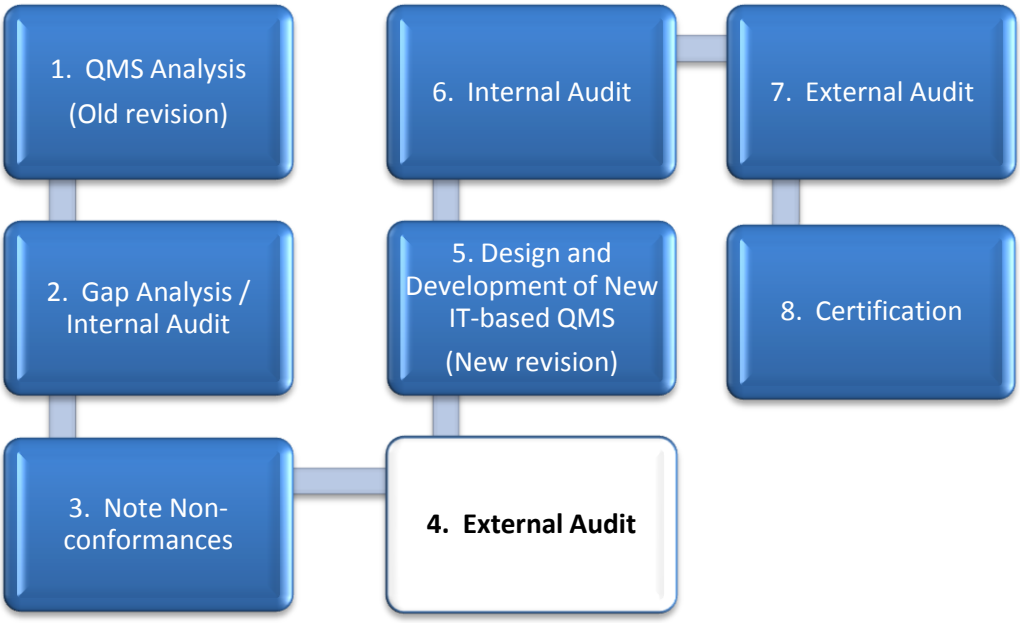

Figure 17: Steps of the Case Study

After the internal and external audits and the research into literature, the gap that the business still had to fill in order to adhere to the quality standard could be determined from this data. These opportunities for improvement have been focused on in the design and development phase. The current state and proposed outcomes are listed in table 9.

Table 9: Current Status versus the Proposed Outcome of the QMS Document

The QMS in its current state:	**Proposed solution/outcomes:**
• QMS based on AS 9100 Rev B • Difficult to audit • Quality Manual (28 pages) • Quality Procedures (79 pages) • Hard copies in five offices • Repetition of information in manual and procedures • Not user-friendly • Procedures based on previous revision	• Update of QMS, based on AS 9100 Rev C • Audit-friendly (better format) • More user-friendly manual that is easily accessible • Fewer hard copies • On Intranet (Read-only) • Editing will be password-protected • Logical flow diagrams with links to records and documents that are kept/used • Written in MS Visio with links; read in PDF

Results from the external audit indicated seven minor non-conformances, which can be seen as a gap that needed to be filled. It was also used as an input into the building phase in Chapter 6.

6. Design and Construction of the IT-based QMS

In this chapter, the actual design and construction of the new IT-based QMS are described. The author first describes how market leaders in the aerospace supply chain operate their quality management systems; these systems set a benchmark against which the QMS could be designed and built. The steps that were followed in the design and development phase of the actual QMS are described with reference to secondary and primary data. The procedures were written with the guidelines of the AS 9100 revision C standard as well as the AS 9101D checklist. The importance of IT is explained to emphasise the advantage gained by the improved QMS, which was introduced to the research partner's intranet and is now functioning as an interactive quality tool. The step in the action research model that was followed is called "Action Taking" as highlighted in figure 18. The author selected a course of action with the help of literature and observations of industry leaders.

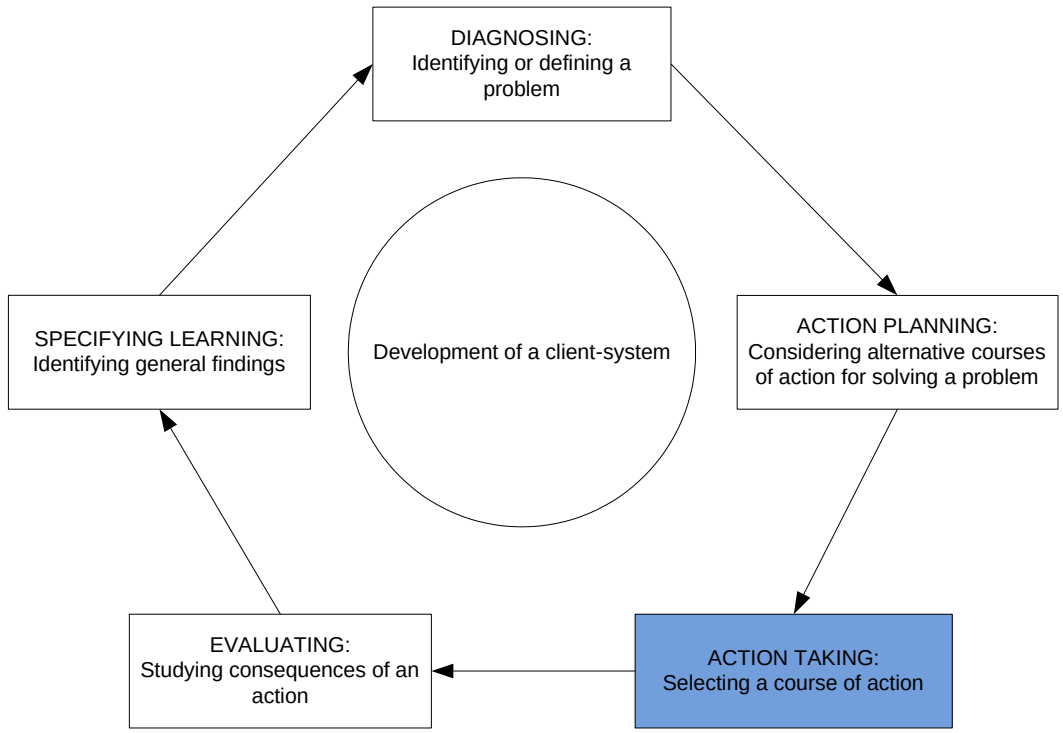

Figure 18: The cyclical process of action research (Susman 1978)

6.1 The Design and Development of the research partner's QMS

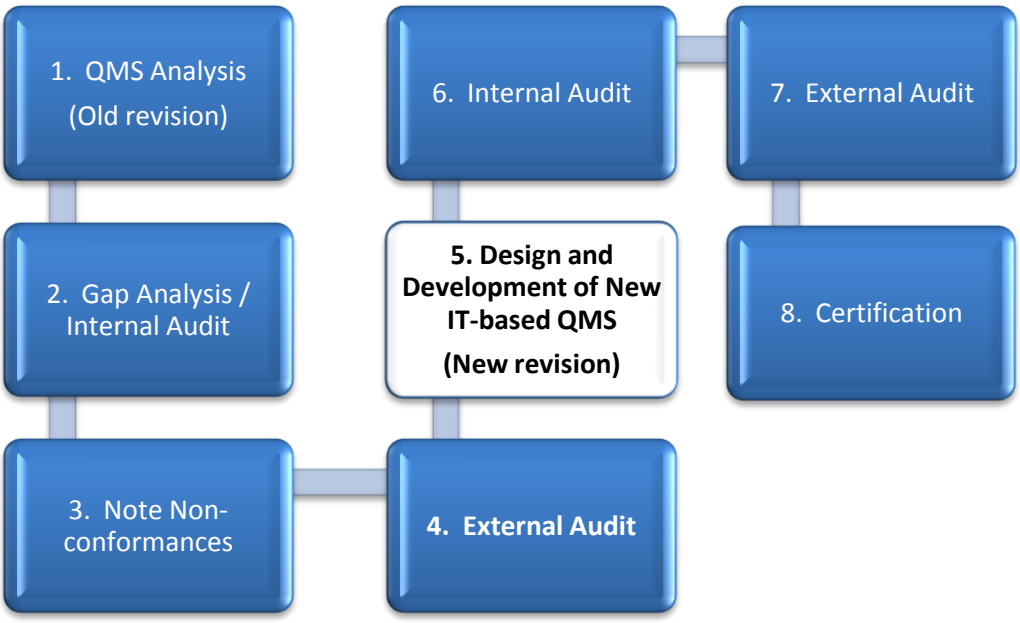

Figure 19: Steps of the Case Study

For a change process to be successfully executed, a thorough understanding of the current (as-is) state of the system is necessary. IDEF0 functional analysis technique is an extremely versatile tool and this method was selected to describe the project of the research partner's QMS design and development process. According to (Harun, Cheng 2010) IDEF0 is the most popular among the practitioners in the aerospace industry because of its superiority in terms of "simple graphic, conciseness, rigor and precision, consistent methodology, level of abstractions, and separation of organization from function"(Harun, Cheng 2010). The AS 9100 standard is based on ISO 9000 which is modeled as activities, information and their flows. This makes IDEF0 the appropriate modelling method.

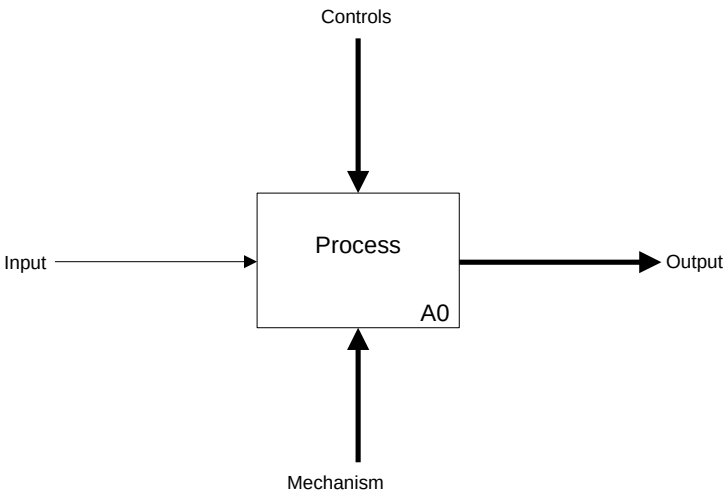

Figure 20: Description of IDEF0 (Harun, K 2010)

The Figure 20 describes the flow into and out of the activity box.

Other literature that served as guidelines in this section

are, *How Boeing A&T Manages Business Processes* (Garretson, Harmon 2005), *A Practical Field Guide for AS 9100* (Myhrberg, Crabtree 2006), *The AS 9101D Checklist* (ASE International Group, AS9101D 2010) and others which will be referenced later in the chapter.

6.1.1 Define quality policy

A quality policy statement is a requirement of the AS 9100 quality management system (Clause 4.2.1.(a)). The decision regarding the quality policy statement is one of the most important steps during the development of a new quality management system. According to Timothy Macenroe in the article, *How to Formulate your Quality Policy Statement and Quality Objectives in your ISO Quality Manual* (Macenroe 2007), it can be regarded as the general guiding philosophy of the company. He also compares the guiding of the company to the steering of a ship. If one compares the quality policy in those terms to sailing a ship, the policy statement could be to sail to destination A. One can then go into more detail: the aim is to sail to Destination A in X number of days and deliver Z products in the desired condition to achieve 100% customer satisfaction.

After a meeting with the management team, the quality policy has been decided upon. It was documented and will be revised and updated at planned intervals. The planned intervals were also stated by the team. The quality policy states the business objectives that support the mission of the company. Examples of objectives of a company include: customer satisfaction, on-time-delivery, safety, productivity, cycle time and performance.

6.1.2 Define goals for quality objectives

The goals for the objectives stated in the quality policy are indicated in this step described by Figure 21, but can be adjusted at a later stage in the building process when more information about the procedures is available. Examples of goals will be discussed briefly.

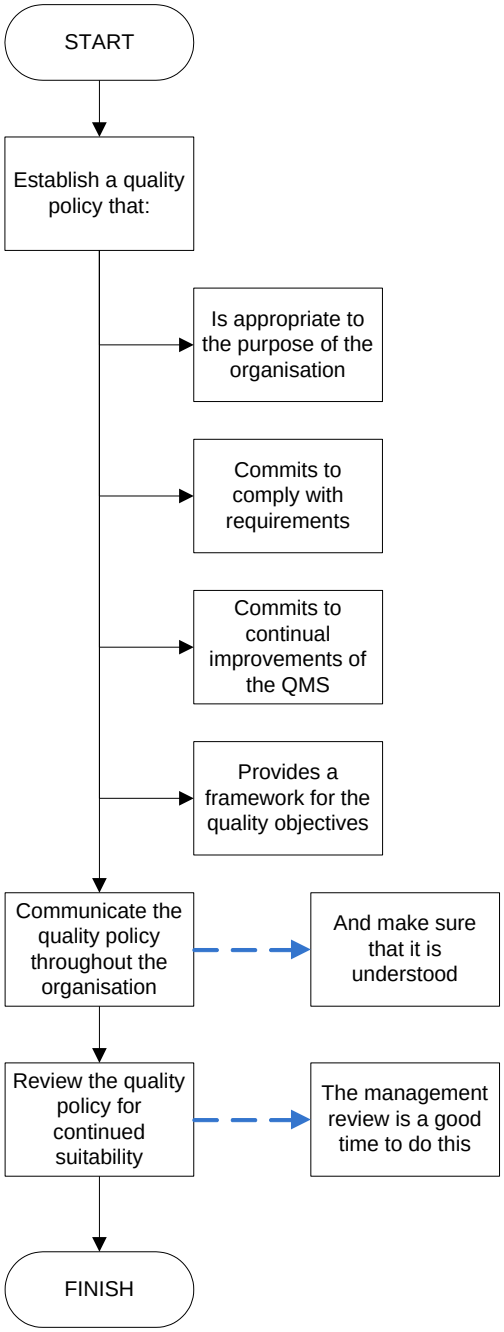

Figure 21: Guidelines to establish a quality policy (Myhrberg,E.V. 2006)

Customer Satisfaction

Is the customer satisfied with the quality of the packaging, the product's functions and features?

Time to market

How long does it take between the conception of the product and its availability for retail? This factor is very important in industries where products are outmoded quickly.

On-Time Delivery

Does the due date match the suppliers' delivery date of suppliers? Is the product delivered to the customer on time?

Cost Savings

Calculating the costs that are saved when using quality tools

Return On Investment: (ROI)

Demonstrate return on investment to stakeholders for quality improvement and identify where financing realignment is necessary to support improvements in quality.

Productivity

Does the quantity correlate with the quality of the planned production?

Performance

Does the production line function in the most effective way possible?

Cycle time

How long does it take to manufacture a whole batch?

Quality objectives should be measurable and based on numerical data. They should be achievable and employees should be motivated and continually updated on the status of the objectives. This is achieved by the research partner by means of a report on their intranet that indicates the status of the objectives. The general guideline is to limit the number of objectives in the policy statement to seven; if it contains more than seven, they can become redundant and if it contains less than three, they might be inadequate. Examples of measurable objectives are the following (Macenroe 2007):

Customer Satisfaction Rating: 97% or better

Customer Returns: less than 10 per month

Customer Returns: less than 0.5% of sales

Final Inspection Rejection Rate: less than 0.5% of units produced

The objectives that the research partner will measure are: the number of non-conformances, time taken to measure first-offs, defective parts, value of scrap parts and customer complaints.

Non-conformance is registered immediately and allocated a unique number. The non-conformance is passed on to the relevant department heads for further investigation or root-cause analyses. Ownership of this system is the responsibility of the Quality manager. A first-off inspection book has been implemented to monitor the time taken for first-offs. The duration of jobs being inspected and the number of defective parts which result in a loss to the company can be seen from these findings. A final inspection book has been implemented to monitor that the time jobs are in final inspection. A non-conformance cost to company book has been implemented. This monitors most rejects, scrap and mistakes that the company cannot recover in monetary value. Customer complaints are followed up immediately by the quality manager by means of direct communication to discuss the problem and instigate the necessary action.

An analysis of these statistics can point out trends or problem areas. This analysis will be discussed at the periodic Management Review Meetings and the actions to rectify these problem areas will be assigned to responsible persons, as well as target dates for their rectification.

6.1.3 Business Process Mapping: Process mapping and linking it to strategies

The goals the business aspires to reach have now been identified. The processes that the business will follow to reach these goals should be listed and mapped in the correct sequence. A flow diagram can serve as a mapping tool. It describes the correct flow of the production cycle from the start to the final product and its delivery.

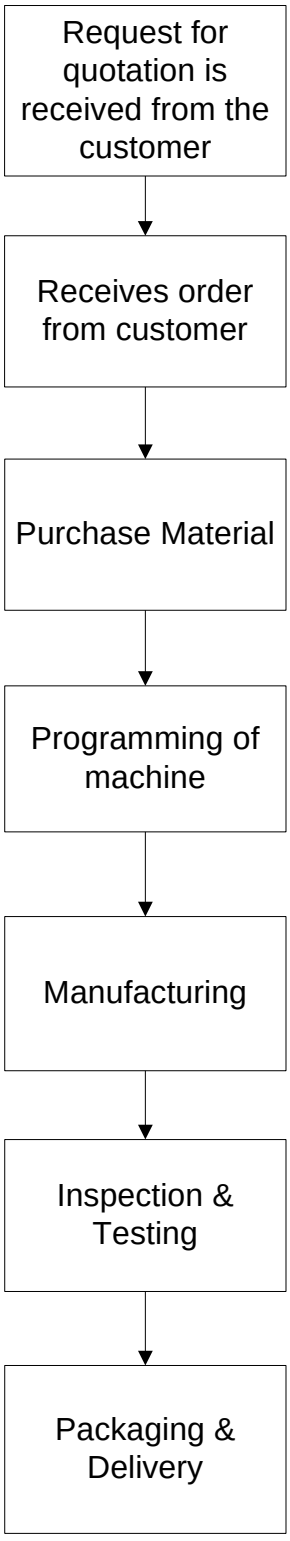

Figure 22: Research Partner's Main Process

The research partner's production cycle will be used as an example: it manufactures high-quality aerospace parts, from raw material to final parts, and ensures their delivery.

6.1.3.1 Description of the main business process:

Firstly, the research partner receives a request for quotation from the customer. The management representative has to clarify any uncertainties with the customer and evaluate the capability of Daliff to meet the requirements that they specify. A risk analysis also needs to be performed to determine whether they will be able to meet the delivery date requested by the customer.

If the analysis is in order, the customer will be provided with a quote; if he is satisfied with the quote, the customer will place his order and the planning department will convert the quote into an order. A purchase order is made and a job card is created.

After this, the CNC programmer will receive the Job Card, Drawing, Specification and work instructions and write the CNC programme for the job.

When the material arrives, the buyer sends it for incoming inspection before it is stamped and paid for. The job is now ready to be manufactured and just awaits its release order from the production manager. Production starts after the production manager releases the order and, if necessary, discusses the work instructions with the artisan. The programmer transfers the programme electronically to the machine, the material is received and production starts.

A first-off part will be made to measure and inspect and it will be marked as the first-off. Subsequently, production of the rest of the batch will start. If the customer specified in process inspection or the programme requires it, the operator will take the parts to be inspected at certain steps in the production.

After the final products were machined, it will be handed over for inspection. At inspection, the dimensions indicated on the job card will be measured and the inspection report will be filled in.

From inspection, the batch will go to the dispatch area where it will be packaged and stored until a delivery vehicle transports it to the customer. The main process was described in Figure 23. The whole IDEF0 model is attached in Appendix B.

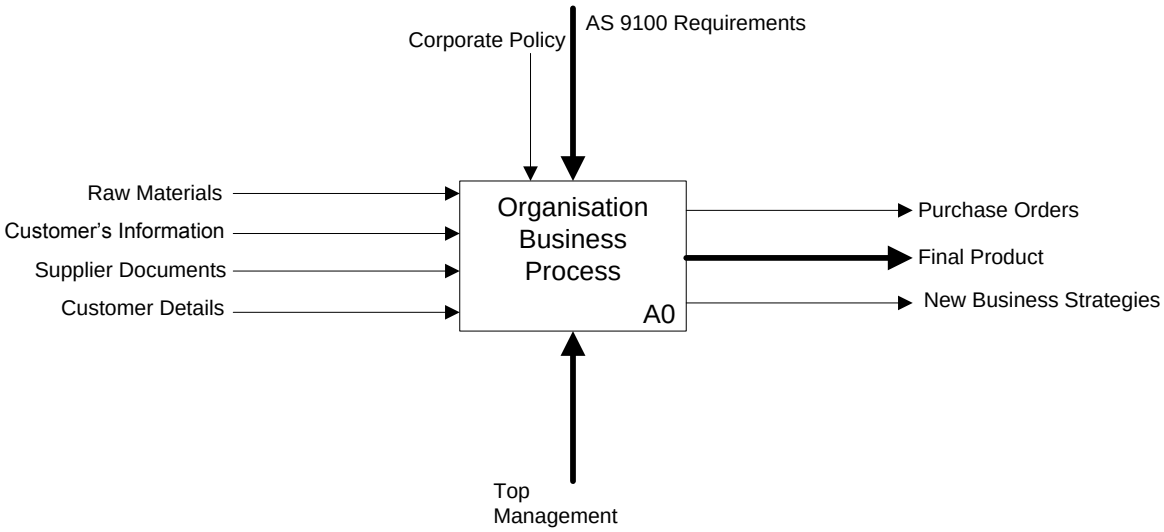

Figure 23: IDEF0 Main Process of the Organisation

6.1.4 Sub-processes:

In this step, the processes and their sub-processes were determined. They were mapped and their interface with each other concluded. Responsibilities were assigned and the level of the processes established.

The business's main process map contributes a great deal to this step. Every process was listed on its own page and the sub-processes needed in that process determined. For every sub-process, the process owner and responsibilities are noted and linked to a main procedure.

A process has an owner, it is defined and normally documented. There are certain links to one another. A process is monitored and measured and records must be kept about this part of the process.

The process owner has the responsibility and authority for effective process operation and must also define what the goal or objectives of the process are. The owner can assign responsibilities according to the specific competence of personnel.

The action researcher and process owners had work team meetings to determine the exact workflow, as well as clearly defined inputs and outputs for every process. The input refers to the requirements of the customer and the output is the deliverables of the process, for example the fulfilment of the need identified in the input phase.

6.1.5 Assign targets, objectives and measures for processes

The qualities objectives that were determined in Step 2 were then assigned to the relevant procedures where they were measured. It could then be measured in each process to gauge how well the process is achieving planned results. An example of a "Production Process" measurable might be the percentage of non-conforming parts in each batch, as the example in table 10. Next to each measurable, a goal to gauge its performance is determined. The goal should be achievable and there must be short- and long-term goals. An example of a short-term goal will be to keep the company morale high as progressively higher goals are set and hopefully achieved.

Table 10: Example of Spreadsheet for the Research Partner's Measurables

Functional Area	Indicator / Measurable	Target	Unit	Owner	Frequency	DECEMBER '10			
						week 1	week 2	week 3	week 4
Marketing / Mng	Customer satisfaction	0.50%	Rating (First time right)	NL	Monthly				
Marketing / Mng	Turnover	>R1.2m/month		NL	Monthly				
Marketing / Mng	Profit	>R0.1m/month	actual vs budget (R)	NL	Monthly				
Marketing / Mng	% quotes achieved	>70%		NL	Monthly				
Marketing / Mng	total quotes (outstanding)	>R0.5m	(R)	NL	Monthly				
Marketing / Mng	New customers or pipeline	2 new cont, 1 new customer/m		NL	Monthly				
Facilities	Machine Maintenance	85% availability	% & hrs	KL	Monthly				
Facilities	calibration of machines	100% of schedule achieved		KL	Monthly				
Production	Safety (amount of injuries)	180 day injury free		KL	Monthly				
Production	Utilisation (OEE)	80%	%	KL	Monthly				
Production	cost performance	>-15%		KL	Monthly				
Production	Overtime cost	0.5% of turnover	Rands	KL	Monthly				
Production	Quality (scrap & Reworks)	0.1% of turnover		KL	Monthly				

6.1.6 Building of the System: Procedures and the Quality Standard

Since the literature about the AS 9100 standard has been discussed in the previous chapter, it can be used as a guideline to determine the following aspects of every process: Policy, Routine, Instructions, and Checklist according to the Standard, as well as the documents needed and records to be kept.

The steps completed up to this point can be used with the support of Figure 24 below to write up the quality procedures (Myhrberg, Crabtree 2006).

The procedures that existed were identified and the people involved in every procedure were determined. In this step, the owner of every procedure was identified. A list that indicates the relationship between the AS 9100 standard and the functional areas was compiled and used as a guideline.

The author documented all the procedures as work flow diagrams, together with each of the process owners and the quality manager. The writing of the procedures is an iterative process and was performed until the procedures were sufficient and adhered to the requirements which it had to conform to.

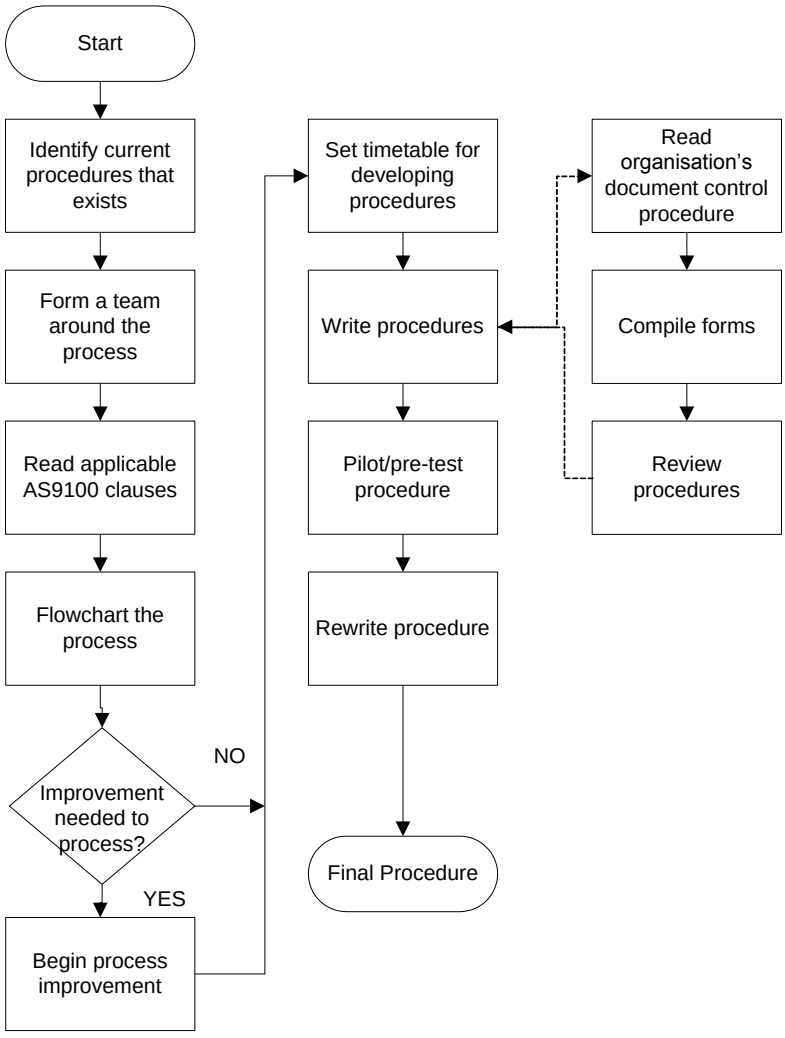

Figure 24: Quality Procedure Writing Process Flow Chart (Myhrberg, Crabtree 2006)

The procedures that already existed as well as the additional procedures that had been determined during the brainstorming sessions of the previous steps were sorted under the following main procedures:

- Procedure 1: Top Management
- Procedure 2: Quality Management
- Procedure 3: Human Resources
- Procedure 4: Continual Improvement
- Procedure 5: Marketing and Sales
- Procedure 6: NC Programming
- Procedure 7: Procurement / Purchasing
- Procedure 8: Calibration
- Procedure 9: Manufacturing
- Procedure 10: Machines and Tooling
- Procedure 11: Safety Health and Environment

These procedures can be categorised into three main areas, namely management processes, manufacturing and planning processes, and facilities.

After the finalisation of all the procedures, a business has to decide upon the flowcharting software it is going to use. This is a decision that will be made by top management, together with the quality manager. In this case study, MS Visio was used to capture all the flowcharts and create links between the pages of the document. The users of the system must be able to easily navigate inside the document itself.

Print screen images of the main pages are described and extractions of the actual QMS are attached in the Appendix. If one scrolls over the blocks, the cursor will change if the block contains a link to another page. One can navigate between the different pages with the help of the home button on every page that will direct the user back to the home page. On the home page of the QMS shown in Figure 25, links are designed to direct the user to the company profile, organisational structure, quality policy, vision and mission statement and the quality objectives. The most important page that the home page links to is the procedure page showing in Figure 26. On this page, the main procedures are listed in a self-explanatory way. It provides a clear picture of the related procedures grouped together in different sub-circles. Top Management is listed on its own in the main circle, like an umbrella, and includes all the procedures.

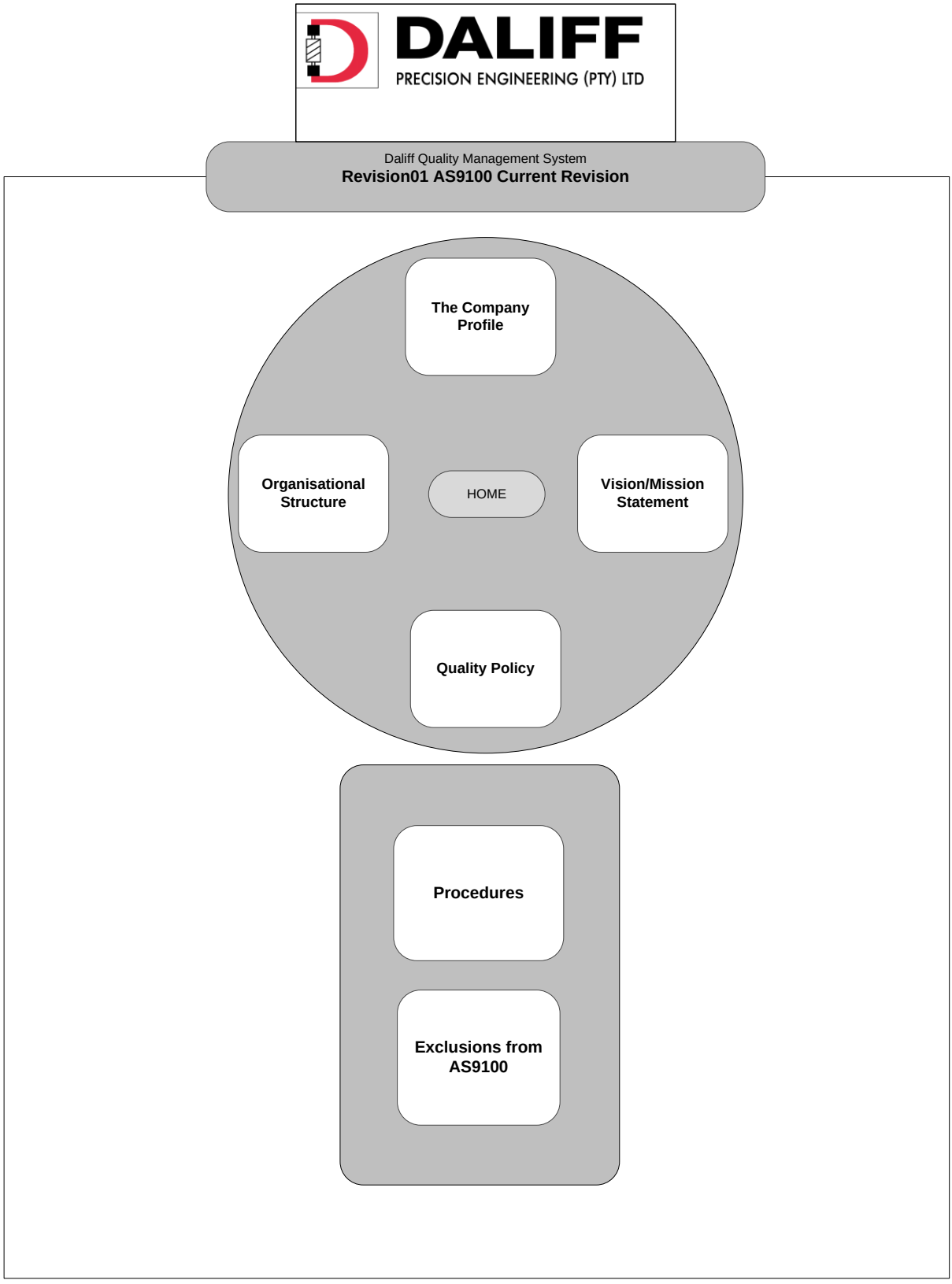

Figure 25: Homepage of QMS

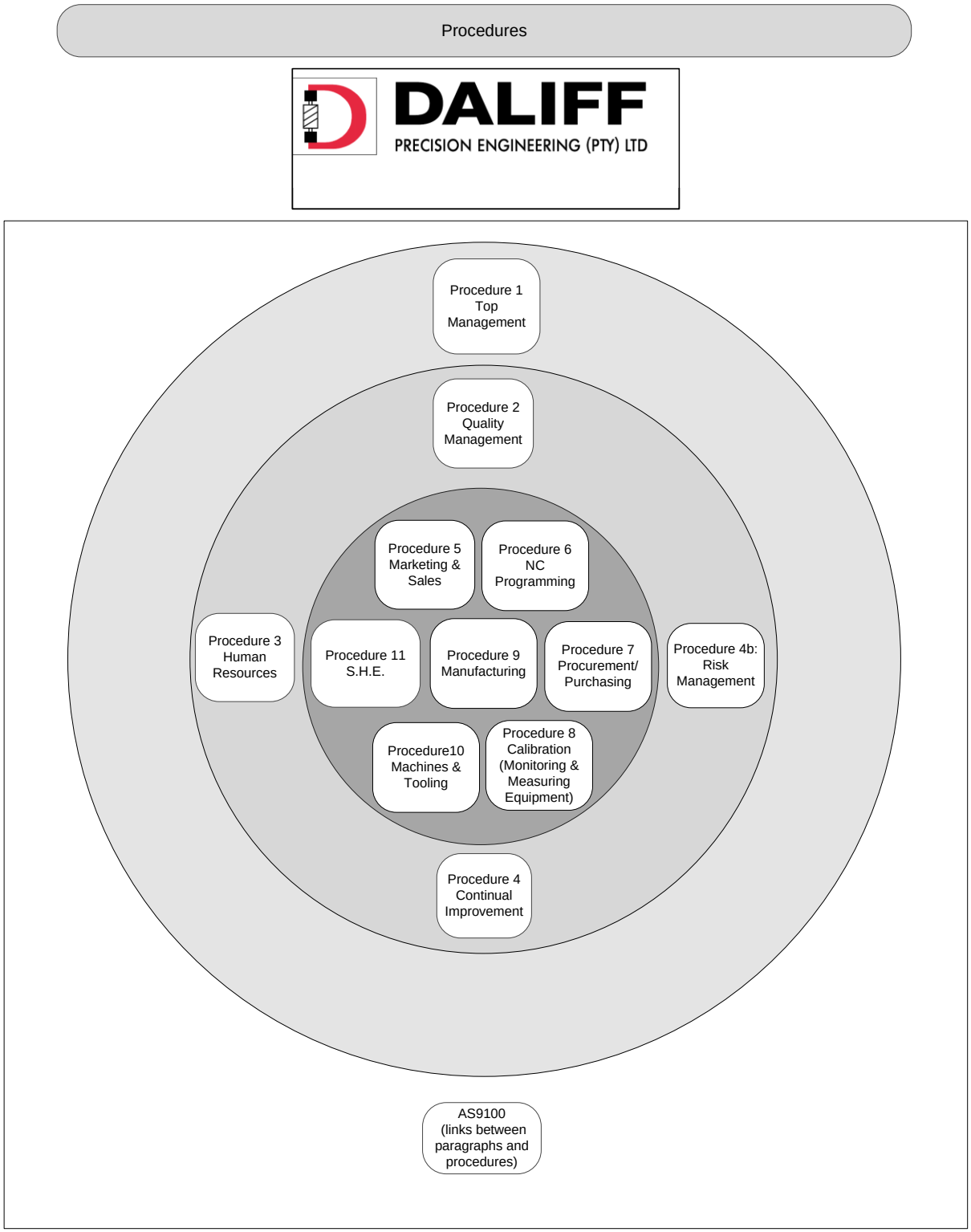

Figure 26: Procedures Layout Page

AS 9100 Requirements and Descriptions

To determine whether the quality management procedures contain all the requirements of the AS 9100 Standard, the AS 9101D Checklist for auditing and the AS 9100 Standard itself were used as guidelines. The documents and records that support these processes as well as help with traceability had to be linked in the QMS as well. In the Appendix, a document is provided which shows the relationship between the procedures and the Standard. This document was compiled according to the AS 9101D checklist, AS 9100 Standard and with the support of the external audit reports (Bureau Veritas Audit Team 12-05-2010, Bureau Veritas Audit Team 09-05-2009). Each of the five main Clauses was described in the following sections. The required documented procedures, documents and records are listed in the tables with the correlating clause number from which the requirement originated. The type of the document will be indicated with a P (Procedure), D (Document), R (Record) or M (Manual). Only the IDEF0 Level 1 activities were explained in Clause 7. The rest of the IDEF0 model is attached in Appendix B. All the requirements of AS 9100 are covered in the model as a control for the processes. Every process has its set of different requirements that it covers.

6.1.7 Clause 4: Quality Management System

The study determined that the research partner's quality management system was already established and documented according to AS 9100 revision B and in the format of ISO 9000:2000.

Table 11: AS 9100 Documented Requirements for Section 4

Section	Title	Description of input	Type: R, D, P
4.1	General		
4.2.1	General documentation requirements		
4.2.2	Quality manual	Quality manual	M
4.2.3	Control of documents	Documented procedure	P
4.2.4	Control of records	Documented procedure	P

Implementation of the Standard in the Procedures

Clause 4.1

General requirements for the quality management system are similar to those of ISO 9001:2008; the QMS for the aerospace industry must also address customer, statutory and regulatory requirements. For example, on their job card the research partner indicates special requirements from the customer, or other instances.

Clause 4.2

Quality manual

The research partner had already established a quality manual that included the scope of the QMS. It was revised to describe the previous and newly identified documented procedures as well as the interaction of these processes within the QMS. The relationship between the specific clauses of the AS 9100 Standard that were used or addressed in the procedures had to be referenced and clearly shown according to the previous revision B. This clause has been removed and auditors now need to identify appropriate documented procedures as an inherent part of the audit. This implies that the QMS be written in such a way that it is easily read and clearly meets the requirements of the Standard.

If requirements are passed down to other organisations, such an action must be stated in the company's QMS (Clause 4.2.1(f)). An auditor may request the documentation of proof from the regulatory agencies that have requirements applicable to the organisation or the product they produce. For the purpose of this study, a list that references the AS 9100 clauses to specific departments and areas is included in Appendix A.

Control of documents and records

The management team should define the documentation needed for every procedure as well as the records which must be kept for traceability. Special consideration should be given to contractual requirements, acceptance of standards, regulatory requirements, organisational decisions as well as the needs and expectations of all the relevant parties. (Myhrberg, Crabtree 2006) Clause 4.2.3 (g) is an addition to the ISO 9001 standard. It aims to keep those that need to know informed; its purpose is to prevent unintended consequences. It may apply to customer-supplier documents. The way in which changes in external documents are handled needs to be documented and performed accordingly. Proof of this may be asked to be presented to an external auditor.

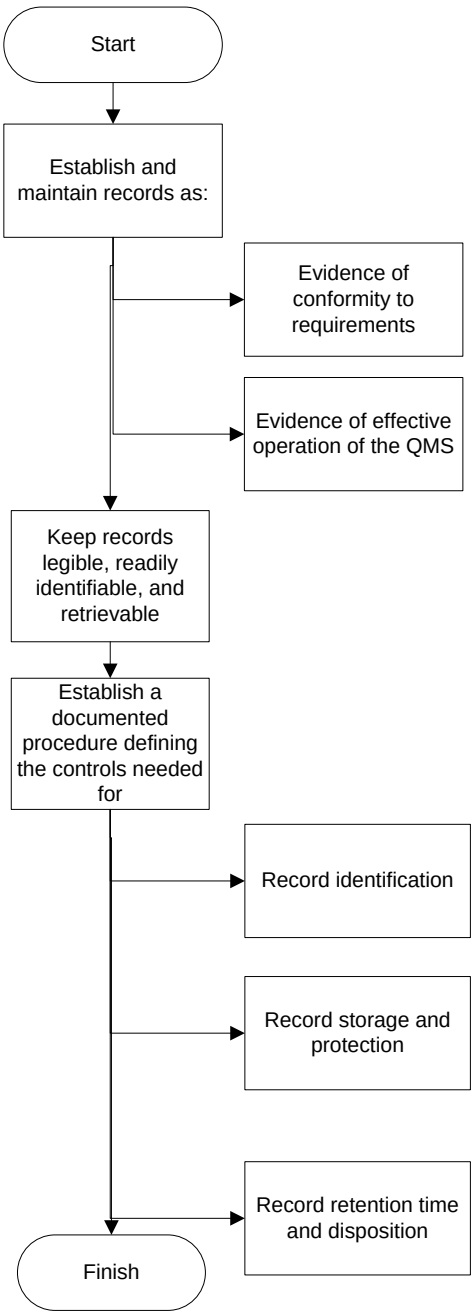

Figure 27: Guidelines to Establish and Maintain Records (Myhrberg,E.V. 2006)

Prior to document usage, evaluate the generation, use and control method of the documentation against criteria such as functionality, user-friendliness, resources, policies and objectives, managing knowledge, benchmarking documentation, and interfaces if it is used by external sources (Myhrberg, Crabtree 2006).

The author created a documented procedure for control of documents and records (see Appendix C) with the guidance of figures 27, 28 and 29. The process owner of the control of documents is the Management Representative. This process is relevant to all documents used in the QMS and its activities. A controlled document will have a Title, Document number, Revision indicator, Page number, Date issued or revised, Prepared by and issued by, Approval and Document content.

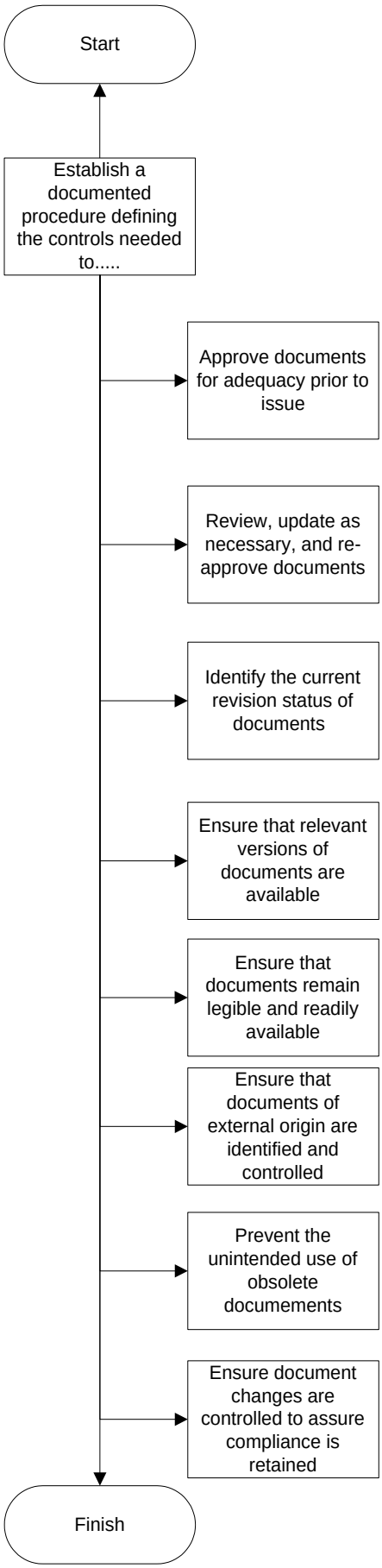

Figure 28: Guidelines to establish a documented procedure (Myhrberg,E.V. 2006)

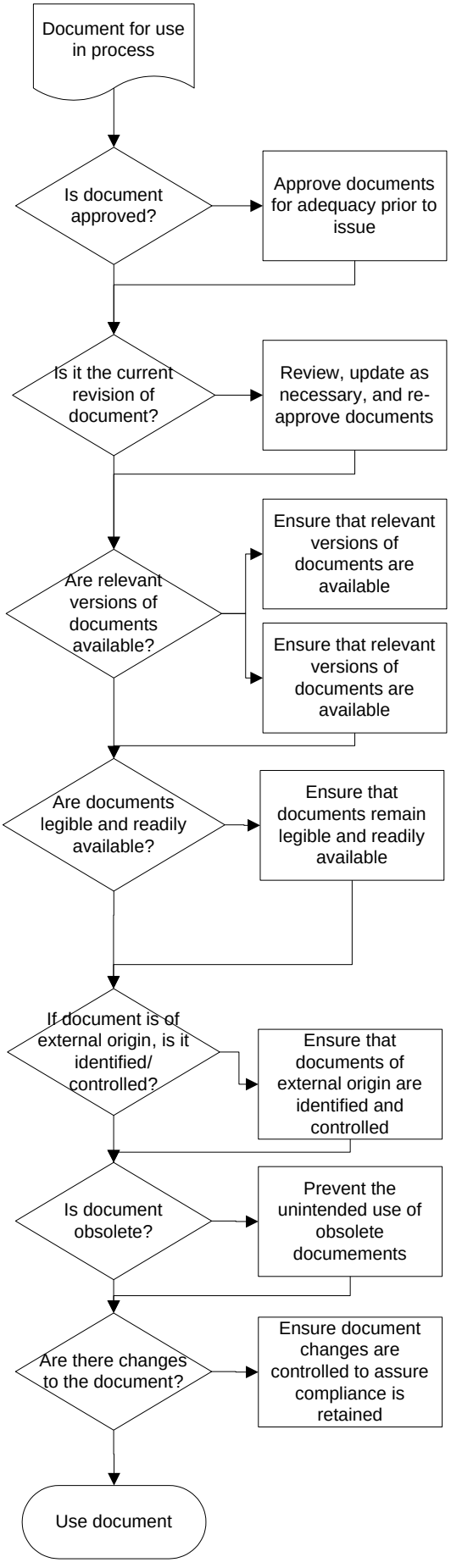

Figure 29: Determining Document Adequacy (Myhrberg,E.V. 2006)

6.1.8 Clause 5: Management Responsibility

The research partner's sub-processes which form part of this clause are:

Procedure 1: Top Management

Management Review

Procedure 2: Quality Management

Internal Quality Audits

Control of Nonconforming Products

Corrective and Preventive Action

In the management review meeting, the results and status of Internal Quality Audits, Control of Nonconforming Products as well as the Corrective and Preventive Action procedures are discussed and documented in the minutes. Table 12 indicates the documented requirements for Clause 5.

Table 12: AS 9100 Documented Requirements for Clause 5

Section	Title	Description of input	Type: R, D, P
5.1	Management commitment		
5.2	Customer focus		
5.3	Quality Policy		
5.4.1	Quality Objectives (planning)		
5.4.2	Quality Management System Planning		
5.5	Responsibility, authority and communication		
5.6.	Management review	Management reviews	R

Implementation of the Standard in the Procedures:

Clause 5.1

The evidence of the commitment of top management's commitment to the development and implementation of the quality management system as well as its continual improvement are described in this clause. The compliance to this clause is illustrated in the customer complaints report and customer requirements, the adherence to the quality policy and objectives, and the results discussed in the management review meetings and the availability of resources.

Clause 5.2

This clause requires top management to ensure product conformity as described by customer requirements and proof thereof.

Clause 5.3

The quality policy has been described in Step 1 of the design and development phase.

Clause 5.4

The quality objectives have been described in Step 2 of the design and development phase, and the quality management system planning was done in Step 6 of the same phase.

Clause 5.5

The focus of aerospace manufacturing stretches the need to have one person inside an organisation who has the authority to speak for the customer or regulatory authority. The position and responsibilities are assigned to this person. It must be documented that this person accepts this position called Management Representative in writing. The Management Representative does not need to seek authority for every action but has the authority to take immediate action that is binding upon the organisation.

Clause 5.6

Proof must be kept of the planned intervals at which the quality management system will be reviewed. The input and output of the management reviews are described. An example of the research partner's management review meeting agenda is attached in Appendix A.

6.1.9 Clause 6: Resource Management

Research partner's applicable procedures:

Procedure 3: Human Resources

Training

Procedure 10: Machines and Tooling

Maintenance of Machines

Procedure 11: S.H.E.

Safety, Health and Environment

Resources include personnel, equipment, repair parts, tooling and/or machine repair and maintenance facilities which can include internal and external maintenance.

The workforce needs to be well-trained in order to perform work affecting the conformity to product requirements. Appropriate records of the education, training, skills and experience need to be maintained. In the case study, the research partner keeps track of these requirements with a competency matrix. Table 13 indicates the documented requirements for Clause 6.

Table 13: AS 9100 Documented Requirements for Clause 6

Section	Title	Description of input	Type: R, D, P
6.1	Provision of Resources		
6.2	Human resources		
6.2.2(e)	Competence, training and awareness	Employee skills	R
6.3	Infrastructure		
6.4	Work environment		

Implementation of the Standard in the Procedures:

Clause 6.1

The resources needed to implement and maintain the QMS as well as ensure customer satisfaction were determined in this clause.

Clause 6.2

A competency matrix was presented as proof for this clause. It presented the records of education, training, skills and experience of the personnel.

Clause 6.3

The buildings, workspace, process equipment and supporting services were identified, provided and maintained to ensure a sufficient infrastructure to achieve the product requirements.

Clause 6.4

This clause describes the ergonomics of the physical workspace in which the activities of the production cycle take place. The workspace will be managed to achieve conformity to product requirements.

6.1.1 Clause 7: Product Realisation

Research partner's procedures applicable to this clause:

Procedure 4: Continual Improvement

Procedure 4b: Risk Management

Procedure 5: Marketing and Sales (Contract Review)

- Quotation Process
- Order Processing and Amendments
- Cost-plus and Emergency Request Orders
- Planning and Prioritising Orders

Procedure 6: NC Programming

- Process Control of CNC Workshop

Procedure 7: Procurement / Purchasing

- Purchasing of Materials, Tooling and Equipment
- Purchasing Sub-contractor Work
- Receiving items from Sub-contractor
- Handling, Storage, Packaging and Preservation
- Customer Supplied Product

Procedure 8: Calibration Inspection, Measuring and Testing Equipment

- Calibration

Procedure 10: Machines and Tooling

- Control of Tooling and Fixtures
- Maintenance of Machines

Procedure 11: Safety, Health and Environment

- Health & Safety and Utilities

Table 14 indicates the documented requirements for Clause 7.

Table 14 **AS 9100 Documented Requirements for Clause 7**

Section	Title	Description of input	Type: R, D, P
7.1	Planning of product realisation		
7.1(d)	Planning of Product Realisation	Product fulfilment records	R
7.2	Customer-related processes		
7.2.2	Review of requirements related to the product	Requirements review	R
7.3	Design and Development (EXCLUSION from the research partner's QMS)		
7.3.1	Design and development planning		
7.3.2	Design and development inputs	Product input requirement record	R
7.3.3	Design and development outputs		
7.3.4	Design and development review	Review records	R
7.3.5	Design and development verification	Verification records	R
7.3.6	Design and development validation	Validation records	R
7.3.7	Control of design and development changes	Design and Development change records Change review records	R R
7.4	Purchasing		
7.4.1	Purchasing Process	Supplier Evaluation list	R

7.4.2	Purchasing information		
7.4.3	Verification of purchased product		
7.5	Production and service provision		
7.5.1	Control of production and service provision	Reviewed work instructions ref.	
7.5.1.1	Production process verification	First Article Inspection (FAI)	R
7.5.1.2	Control of production process change		
7.5.1.3	Control of production equipment, tools and software programmes	Sample of validation records	R
7.5.1.4	Post-delivery support		
7.5.2(d)	Validation of processes for production and service provision (EXLUSION)	Process Validation	R
7.5.3	Identification and traceability	Traceability records ref. Product identification	R
7.5.4	Customer property	Customer property records	R
7.5.5	Preservation of product		
7.6	Control of monitoring and measuring equipment	Register reference Process definition	R
7.6(a)	Control of monitoring and measuring devices	Calibration standards	R
7.6(c)	M&M equipment has unique identifiers	Equipment reviewed ref.	R
7.6	Calibration records are retained	Calibration records ref.	R

Implementation of the Standard in the Procedures:

Clause 7.1

Evidence of how the research partner plans and develops processes needed for product realisation is described in this clause. The records of product fulfilment are required as evidence. It also includes four sub-clauses which were previously part of other clauses but their importance to product realisation was so great that this revision assigned them a position under Clause 7. These four sub-clauses are: project management, risk management, configuration management and control of work transfers. They have been incorporated in procedures 4, 5, 6, 7, 9 and 11.

Clause 7.2 (IDEF0 A1 in Figure 31**)**

Customer-related processes have been addressed in procedures 1, 6 and 7. Clause 7.2.2 (e) refers to the risk management process: in essence, this requirement stipulates that a risk analysis on the capabilities of the organisation to achieve the customer requirements must be performed before accepting an order. This will assist the organisation with recognising risks and their potential impacts, and guide them in action planning to mitigate negative effects. In this way, problems may be prevented. The contract review process in Procedure 5 is proof that this requirement is adhered to as well as the risk management sub-process in Procedure 4.

Clause 7.3

This clause is excluded for the research partner and was not taken into account for the purpose of this study – the reason being that that design and development activities for aerospace parts are not performed by the research partner. The records that need to be kept for these activities are listed in table 14. These activities are the responsibility of the customer and the manufacturing requirements given to the research partner. The author makes the assumption that other SMEs in South Africa most likely will fall in the same category of only manufacturing according to customer specifications. Many SMEs also do work in the defence-, mining-, automotive- and general industries and this means that Design and Development forms an integral part of their QMSs. If this is not the case, specific attention must be given to the implementation of this clause as a further research possibility. If an organisation does engage in the design and development activities, the process consists of a planning phase, inputs and outputs of the design and development phase as well as verification and validation of the designs. The control of changes to the design and development phase also needs to be monitored. According to K. Harun and K. Cheng (2010), the design and development team might use technologies such as CAD and concurrent engineering tools to generate the product drawings and specifications. This team will interact with the production teams to solve problems and monitor the solving thereof. In

the case of Boeing as an example, a team of engineers will be formed to work hand in hand with the Boeing as the manufacturers. The planning of design and development will be illustrated by means of a flow diagram in figure 30:

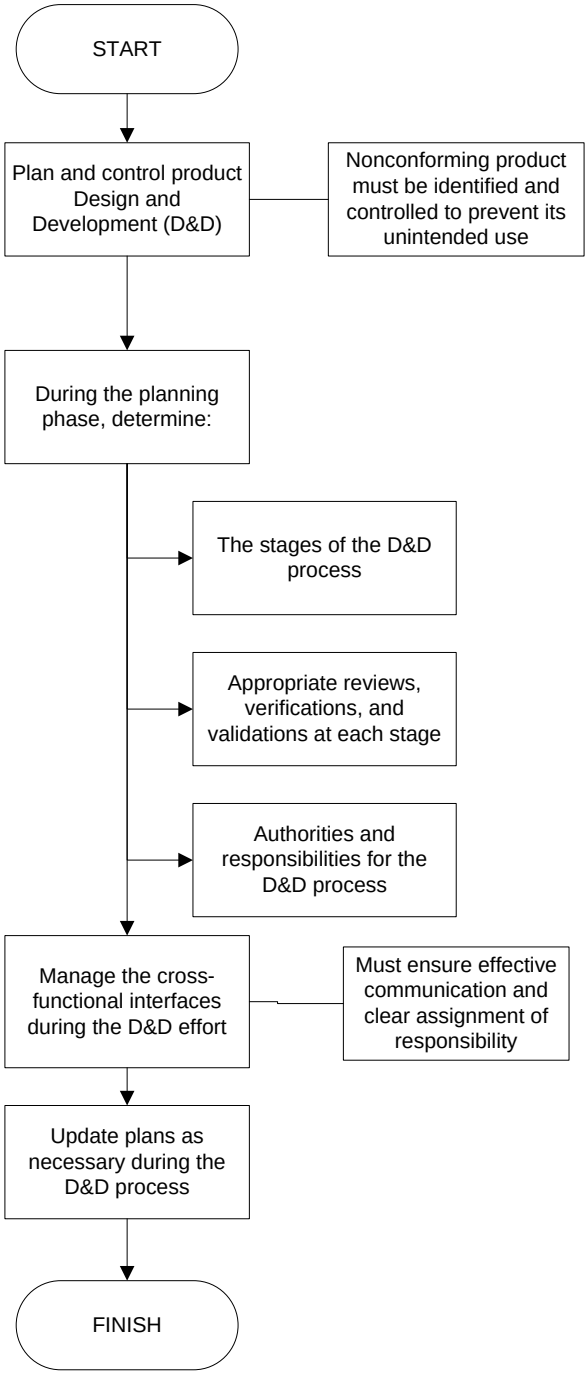

Figure 30: Design and Development Planning (Myhrberg,E.V. 2006)

Clause 7.4 (IDEF0 A2 in Figure 31**)**

This clause focuses on the purchase process; the procedure that has been developed and tested by the author to determine whether it meets the requirements, is Procedure 7. Customers requirements may include designated suppliers for certain materials, components, assemblies and services. This has been included in the process of evaluating suppliers and the registering of approved suppliers. It does not take away the organisation's responsibility to control the quality of such suppliers and it must still inspect incoming material. All the suppliers on the list need to be approved by means of the process defined by the organisation. The research partner does not perform any special processes such as welding or plating.

Clause 7.5 (IDEF0 A3, A4 and A5 in Figure 311**)**

The effectiveness of in-process control methods was kept in mind during the application of this clause. Requirements are printed on the job card which follows the batch from start to finish. The evaluation of the effectiveness of the upstream inspection or control points was put in place to prevent the production of nonconforming products; this was achieved with the in-process inspection procedure. A first-off part is manufactured from every production run or when engineering/process changes occurred. It is included in Procedures 6 and 9. Clause 7.5.1.2 was adhered to in Procedures 6 and 7. Production operations are carried out in such a manner that all the personnel have access to the applicable data and documentation needed. The production documentation is configuration-controlled. Any changes done on the design must be settled with the customer and documented as proof.

Clause 7.5.2 in its entirety is also an exclusion to the QMS of the research partner because the clause states that for any processes for production and service provision where the resulting output cannot be verified by subsequent monitoring or measurement. All the processes for production and service provision of the research partner can be verified by subsequent monitoring and measurement. Processes that cannot be verified are referred to as special processes and typical special processes may include surface treatment, heat treatment, composites and non-destructive testing (NTD).

NADCAP is the name of an international cooperation of large companies in the aerospace industry. NADCAP is an acronym for "National Aerospace and Defense Contractors Accreditation Program" and is a separate brand in order to emphasize international cooperation. In 2003 NADCAP became the principle global standard established in Asia, it was already operational in the U.S. and Europe. The corporation's objective is to cost-effectively standardize special processes and products to achieve continuous improvement in industry. The NADCAP consists of 30 OEMs like. Airbus, Boeing, Pratt & Whitney, Rolls-

Royce and GE who are going through their demands for special processes to achieve common standards. They have standards in special processes, including: non-destructive testing, materials testing, heat treatment, coating, chemical processes, welding and non-conventional machining and processing. NADCAP also conduct audits of those standards themselves. In 2004 2852 audits were done and grew to over 3200 in 2005 (www.pri-network.org). NADCAP audits aerospace suppliers for seven special processes and six systems and products. Processes include:

• Non-destructive testing

• Materials testing

• Heat treating

• Coatings

• Chemical processing

• Welding

• Non-conventional machine and surface enhancement like shot peening.

Systems and products include: sealants, distributors, AQS (AC7004), fluid distribution standards, elastomer seals, composites, electronics and fasteners. Individual OEMs determine which processes or products they will demand accreditation for. Rockwell Collins, for example, will require that its NDT, chemical processing and composite suppliers be Nadcap approved beginning January 2006. What that means for the supplier base is that Nadcap accreditation has become the gateway for many companies wishing to provide OEMs with special processes (B. Rosenberg, 2006).

Clause 7.6

The AS 9100 standard is very specific regarding the nature of instruction documentation required for a compliant calibration system. The calibration procedure was developed for this purpose.

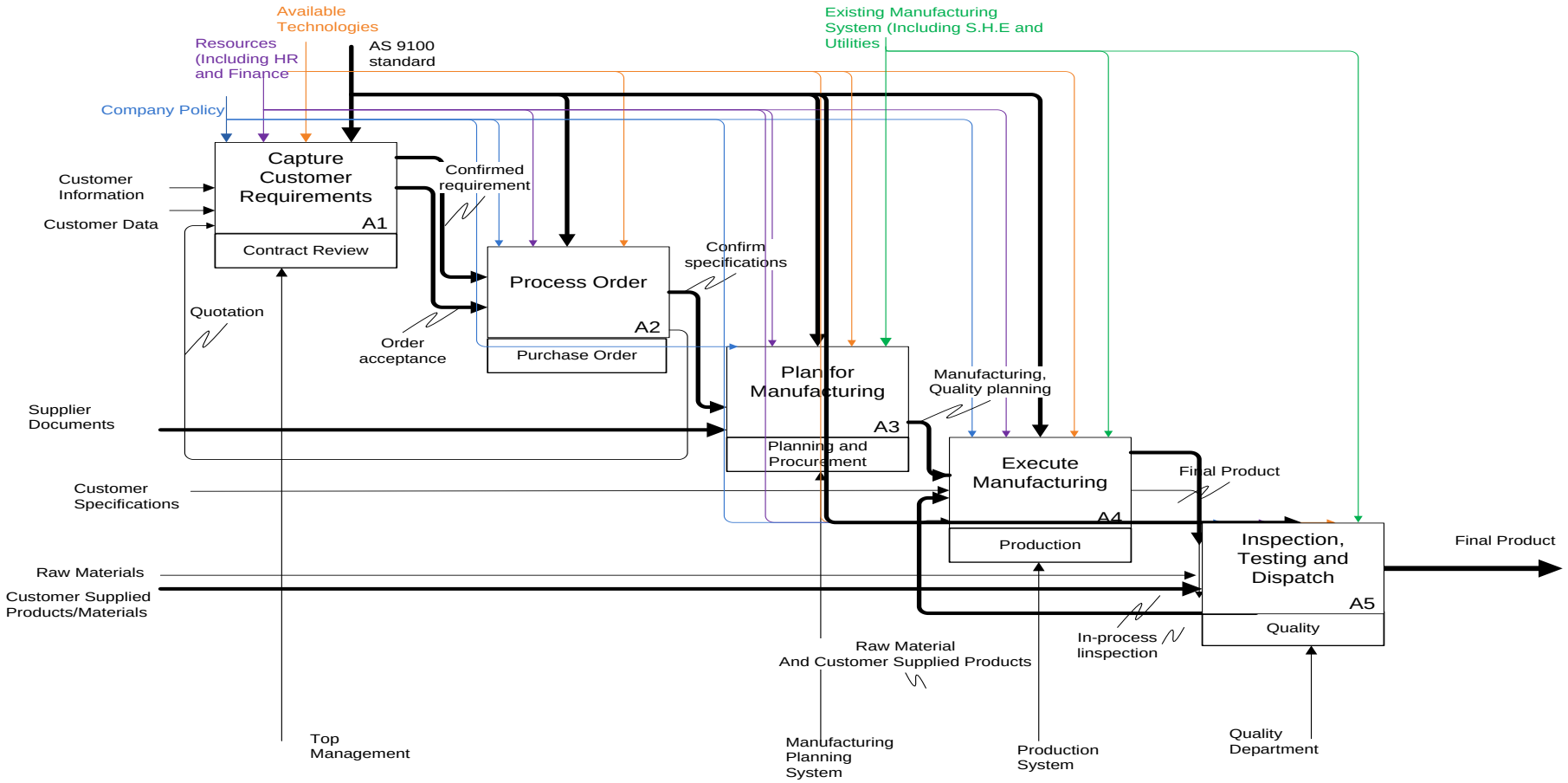

Figure 31: Level 1 of IDEF0 Model of the Activities

6.1.2 Clause 8: Measurement, Analysis and Improvement

The research partner's procedures applicable to this clause:

Procedure 1: Top Management

- Management Review

Procedure 2: Quality Management

- Internal Quality Audits
- Control of Nonconforming Products
- Corrective and Preventive Action

Procedure 5: Marketing and Sales

Table 15 indicates the documented requirements for Clause 8.

Table 15: AS 9100 Documented Requirements for Clause 8

Section	Title	Description of input	Type: R, D, P
8.1	General	Samples of monitoring, measurement, analysis methods	R
8.2	Monitoring and Measurement		
8.2.1	Customer Satisfaction	Methods ref. Improvement plans	R R
8.2.2	Internal Audit	Documented Procedure ref.	P
8.2.2		Audit Results	R
8.2.3	Monitoring and measurement of processes		
8.2.4	Monitoring and Measurement of Product	Product Conformance	R

8.3	Control of nonconforming Product	Documented Procedure	P
8.3		Nonconforming records	R
8.4	Analysis of data		
8.5	Improvement		
8.5.1	Continual improvement	Evaluation of improvements	R
8.5.2	Corrective Action	Documented Procedure	P
8.5.2(e)		Corrective Action results	R
8.5.3	Preventive Action	Documented Procedure	P
8.5.3(e)		Preventive Action taken	R

Implementation of the Standard in the Procedures

Clause 8.1

The general requirements applicable to the measurement, analysis and improvement processes have been taken into account in this clause. It has been adhered to and proof can be found in Procedures 1, 2 and 7.

Clause 8.2

The internal audit procedure was described in the previous chapter (Chapter 5). The monitoring and measurement processes functions are described when analysing the research partner's quality manual and previous QMS procedures.

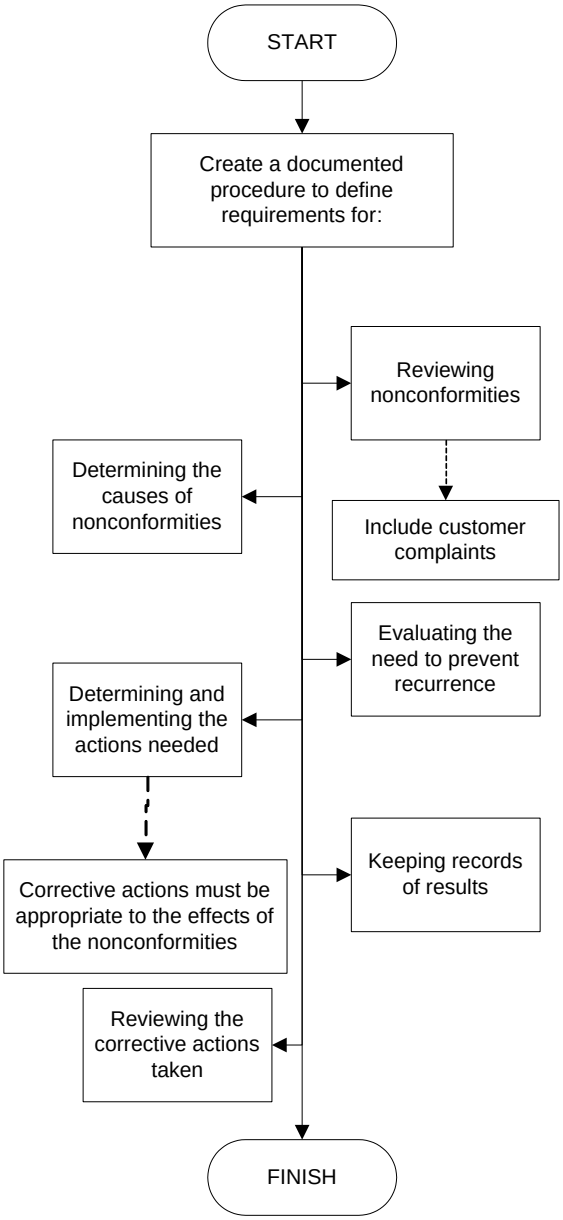

Figure 32: Procedure for Corrective Actions (Myhrberg,E.V. 2006)

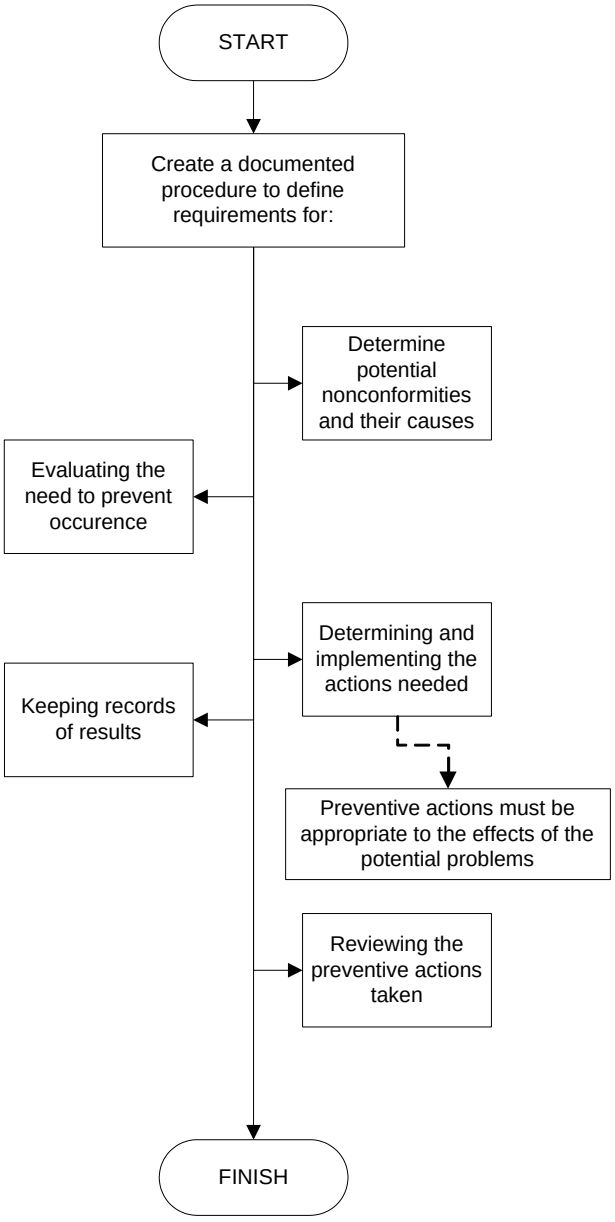

Figure 33: Procedure for Preventive Actions (Myhrberg,E.V. 2006)

After a root-cause analysis to determine the origin of the problem has been completed for the non-conforming product, an investigation into actions that will correct this problem were sought (Figure 322) as well as a plan to prevent it from reoccurrence (Figure 333).

Clause 8.3

Nonconforming products require serious attention and control. The research partner, together with the author, defined the process to review these products and, if required, place under quarantine. The quarantine store list was updated and reviewed for this purpose. Figure 34 was a guideline in determining the procedure.

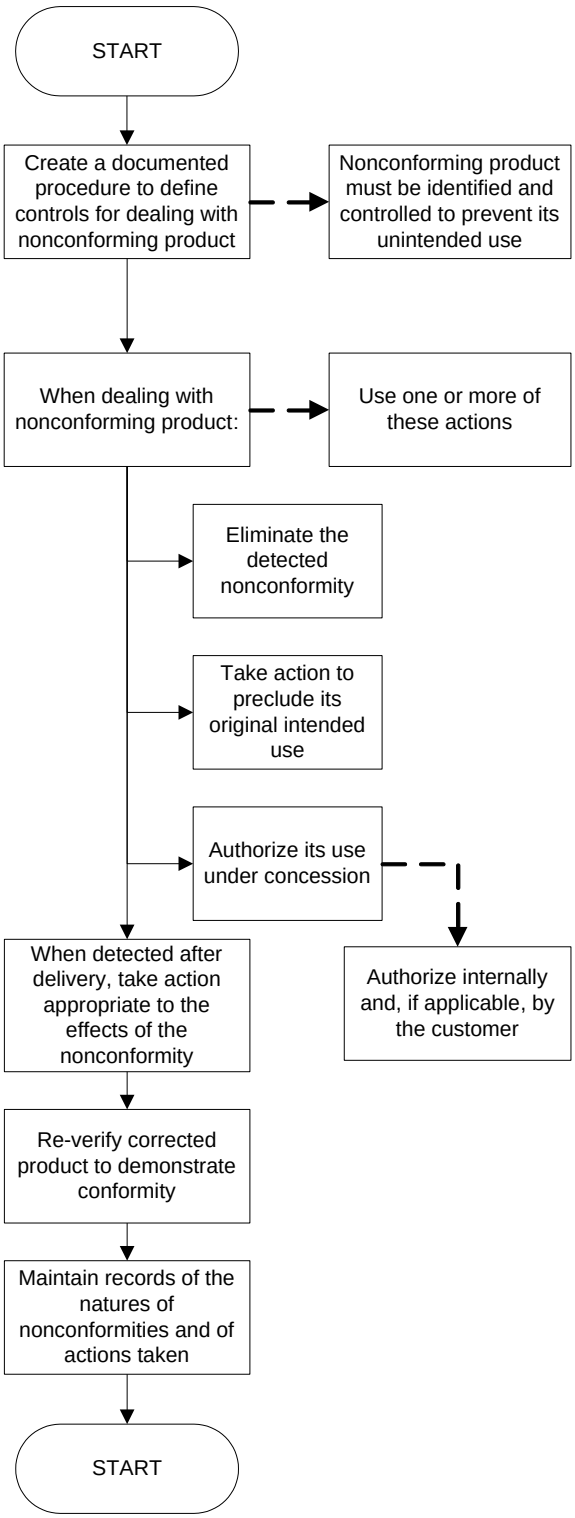

Figure 34: Procedure for Handling of Non-conformances (Myhrberg,E.V. 2006)

Clause 8.4

The importance of continual improvement created urgency for companies to determine, collect and analyse data which will demonstrate suitability and effectiveness of the QMS. Top management will analyse the satisfaction of customers, product non-conformities, possibilities for preventive action as well as the evaluation reports of the suppliers.

Clause 8.5

Continual improvement will result in improving the effectiveness of the QMS by means of the quality policy and quality objectives which will be revised and maintained continuously by the Quality Manager and Top Management.

The inputs to this improvement process are: audit results, analysis of data, corrective and preventive actions and the conducting of management reviews. (Figure 355)

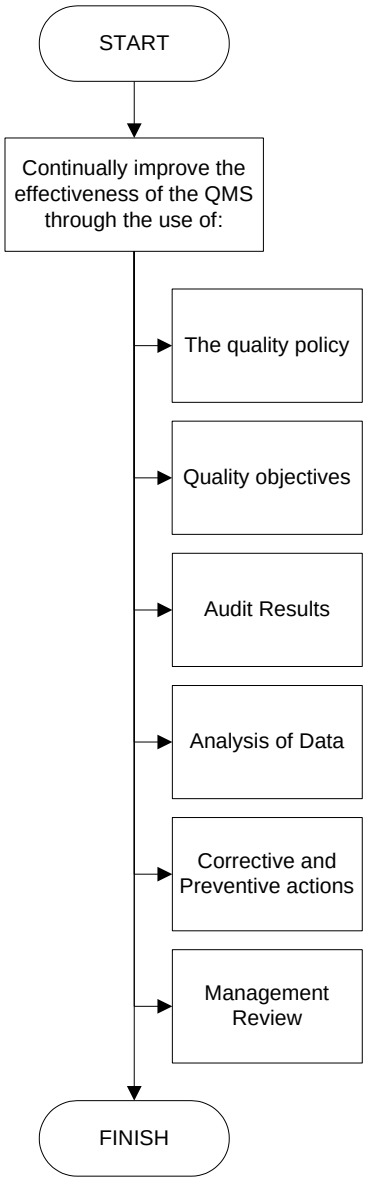

Figure 35: Continual Improvement of the QMS (Myhrberg,E.V. 2006)

General

The QMS which was developed and implemented by the author was published on the business's intranet to ensure all the employees of easy access and create awareness of all the relevant quality management documentation and changes.

The quality management system which the research partner had used previously was used in hard-copy format. It was a controlled document in every relevant office. A lack of resources in the form of time, finances, workforce and skill usually presents obstacles for the maintenance and improvement of the company's quality management system. The consequence may be that the maintenance and improvement become a low priority and are not part of the daily activities. A gap was filled and literature contributed to the problem's solution.

The Intranet

The intranet is a network of documents which functions in a similar way as the World Wide Web, except that it is closed off from the general internet by a firewall. It can only be viewed or accessed within a defined local network.

Advantages of using intranets include the reduction of paper copying, distribution costs, and faster access to information, such as the QMS, in the case of the research partner. It is also much easier to contribute to a maintainable competitive advantage. An intranet is only as good as its content (Howard 1992). The organisational benefits of an intranet can include the raised awareness of and commitment to organisational objectives, the creation of a learning organisation which adapts quickly to changes and provision of a greater degree of flexibility with respect to both technology and people (Howard 1992).

An intranet-based information system (in this case, a quality management system) will increase the involvement of the people who are already intimately involved in the different procedures and parts of the business. It will help to create ownership of the applications and work procedures (Curry 2000).

The problem caused by the research partner's paper-based QMS could be solved by operating the QMS on the intranet. The problem was that the paper-based QMS did not support interactivity and continual improvement and maintenance were extremely difficult to accomplish. It was very important to design and develop the QMS in such a way that it is reliable and user-friendly. The factors taken into account were the frequency and type of web use, web/intranet skills, as well as – especially important – content contribution and training needs. The QMS was developed and:

- Updated to AS 9100 Rev C;
- Is now audit-friendly (better format);
- Has a more user-friendly manual that is easily accessible;
- Has been placed on the Intranet (read-only);
- Its editing and printing will be password-protected (only controlled copies may be printed if requested by external parties)
- Contains logical flow diagrams with links to records and documents or to the folders where they are stored
- Is written in MS Visio with links, read in PDF.

The support of IT in SCM (supply chain management) required that a project management approach be followed; it was done with the right team (the research partner's process owners) and the support of Top Management. Top Management's support is of essential importance to boost morale as well as financial and technical support for the implementation of IT (Gunasekaran, Ngai 2004).

6.1.3 Critical Success Factors when implementing a QMS in an SME:

The AS 9100 Standard is based on ISO 9000 Standard. The barriers that can prevent businesses from becoming ISO 9000 certified must be acknowledged and investigated in the same light as the barriers to become AS 9100 certified. A survey of Singapore companies indicates the following barriers to ISO 9000 certification:(Yahya, Goh 2001)

- Lack of top management support and commitment
- Employee resistance to change
- Lack of understanding of ISO 9000 system (in this case, AS 9100 system)
- Constraints on resources (workforce, time, finances)
- Lack of training and education of employees
- Unclear benefits of obtaining certification

A top-down approach was followed to involve the Top Management of the research partner from the start of the project. This approach resulted in the participation of the whole workforce. If the Top Management understand the requirements of the Standard and are able to educate the workforce sufficiently, this obstacle can be overcome. The workforce took ownership of the activities for which they are responsible.

The benefit of achieving AS 9100 certification is that the organisation can become a competitor in the global supply chain of the aerospace industry. All the AS 9100 registered companies are listed on the OASIS (Online Aerospace Supplier Information System) database of the IAQG (International Aerospace Quality Group) on the World Wide Web. The

certified suppliers' details as well as the certification body and certification details can be obtained from this website.

The surveys and the interviews conducted by The Faculty of Economics and Management of the University Putra Malaysia (Yahya, Goh 2001), as well as the results from the observations of the case study at the research partner indicated the following critical areas for concern when implementing and maintaining a QMS:

- Corrective and preventive action
- Internal quality audit
- Management responsibility
- Document and data control
- Control of quality records
- Configuration management
- Continual improvement

These guidelines were taken into account when upgrading the research partner's QMS. All of these critical areas are described in a flow diagram in the QMS in Appendix C.

7. Validation through Post-Implementation Follow-up Audit at Research Partner

The validation of the built QMS and the process of constructing were validated by means of and internal audit conducted by the author, the second surveillance audit and observing another case study in Sweden. The validity of the project is described in this chapter. The last steps in the case study are illustrated in Figure 366.

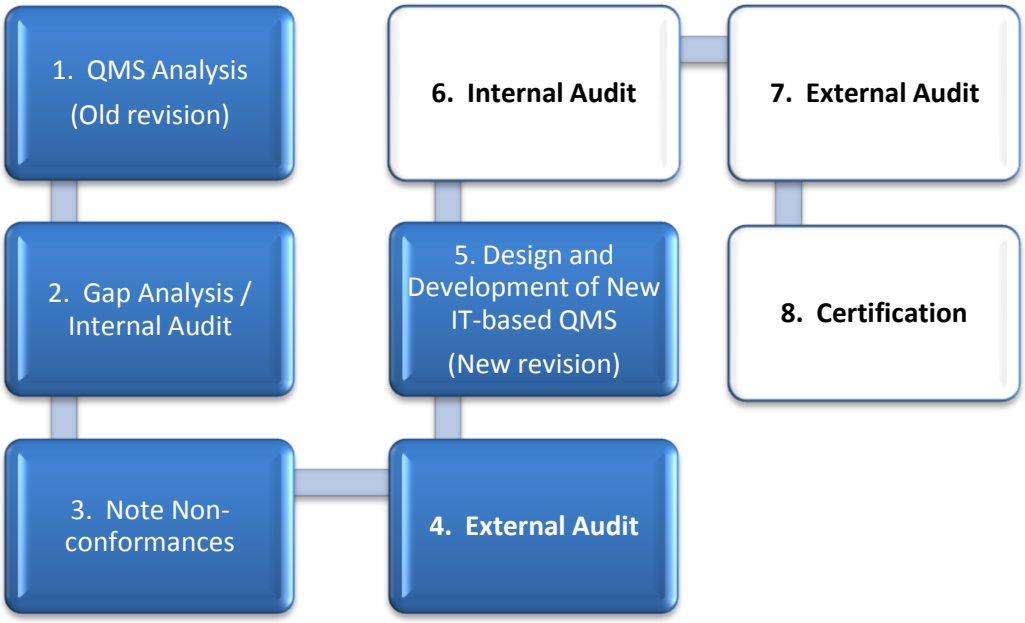

Figure 36: Steps of the Case Study

7.1 Internal Audit

Planning of the internal audit was done in accordance with the procedure described in Chapter 5. The audit plan is attached in Appendix A.

List of non-conformances

The second internal audit was done after the author had analysed the external audit reports of the previous two audits and implemented their corrective actions and the newly developed QMS. All the procedures were checked against the Standard (AS 9100 Rev C) as well as the actual work procedures which were carried out in practice. Although the next scheduled external audit was planned to be against AS 9100 revision B, the QMS was built to already incorporate revision C. As of July 2011, all the audits will be against AS 9100 revision C.

The following list of documented procedures was reviewed (the audit programme is included in Appendix A):

1. Management Review
2. Contract Review
3. Control of Records, Documents and Soft Stamps (including Configuration Management)
4. Purchasing
5. Control of Customer Supplied Product
6. Process Control (including Configuration Management)
7. Inspection and Testing
8. Control of Inspection, Measuring and Test Equipment
9. Inspection and Test Status
10. Control of non-conforming Product
11. Corrective and Preventive Action
12. Handling, Storage, Packaging, Preservation and Delivery
13. Internal Quality Audits
14. Training

Every procedure consists of a purpose, scope, reference documentation, definitions, responsibilities, records that need to be kept, reason for change as well as activities carried out.

The audit was conducted in the following way:

The auditor (in this case, the author) studied the procedure as it is documented and then looked at the clauses in the AS 9100 standard that the procedure referenced. If the

procedure was found to be sufficient, the author started with the audit of the actual activity to find whether the documented procedure correlates with the actual activity in practice. A reference list of the procedures and the clauses covered by them are presented in Appendix A.

7.2 External audit

General

After implementation of the upgraded QMS, the research partner's second surveillance audit was conducted. This audit was conducted against AS 9100 revision B, even though the QMS had incorporated the change to revision C. The Certification Body (CB) still needed its auditors to be trained in order to audit against the new revision which is scheduled for incorporation in July 2011. Figure 37 indicates the time scale transition from revision B up to revision C.

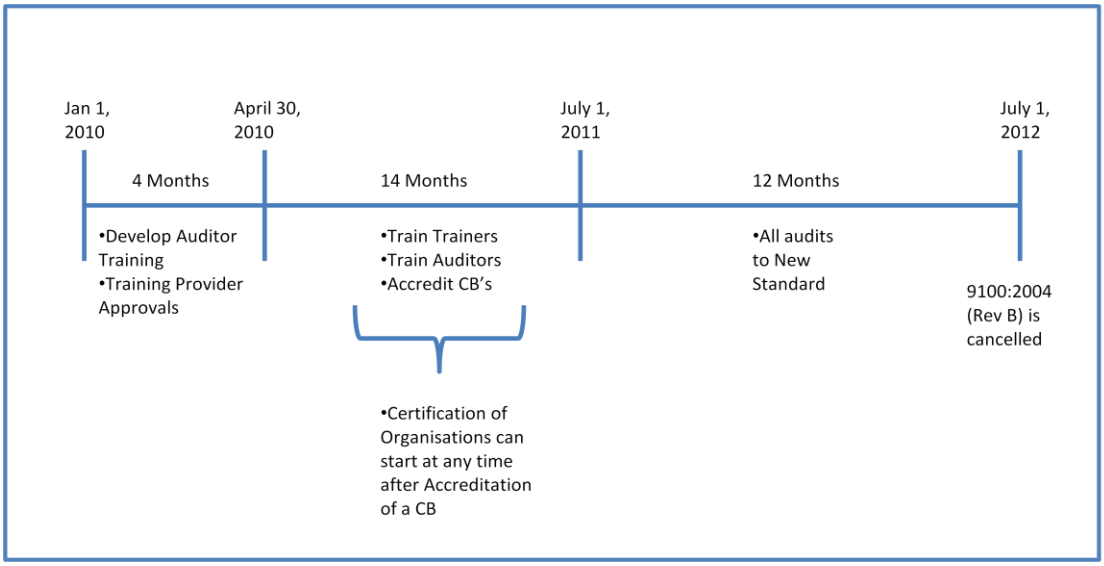

Figure 37: The 30-month transition schedule (According to the IAQG web page)

Functional areas that were audited are: Top Management, Quality Management, Configuration Management, Finance and Administration, Marketing and Sales, Supplier Management, Facility Maintenance, Planning and, lastly, Receiving, Stores and Dispatch. The next scheduled external audit in 2011 will be a recertification audit in which all the functional areas will be audited.

Introduction

This audit was conducted as the second surveillance audit of the research partner. The scope of supply of the organisation was still the manufacturing of precision components. The audit was performed against AS 9100B:2004 and ISO9001:2008 standards.

The objectives of this audit were to determine whether the organisation's quality management system still conforms to the requirements of the standards mentioned, as well as measuring the effective implementation of all its planned projects and arrangements and, lastly, their capability to achieve the quality policy's objectives as stated in the QMS (Bureau Veritas Audit Team 12-05-2010).

The previous external audit results were reviewed and it has been determined that all the non-conformances have been dealt with and were closed successfully (Bureau Veritas Audit Team 12-05-2010).

Nonconformities

There were still eleven non-conformances that were found. All were raised as minor non-conformances as they would likely not result in the failure of the quality management system or reduce its ability to ensure controlled processes or compliant products/services (ASE International Group, AS 9101D 2010).

Feedback from the Audit Report

Clauses 7.3 and 7.5.2 were still excluded from the scope, and this exclusion was indicated and justified in the quality management system; the products which they manufacture do not require servicing and no special processes are performed by the research partner. According to the Audit report, the new electronic QMS was described as a significant enhancement of the system efficiency.

The system performance was measured and the QMS was found to be well entrenched throughout the company and, with the exception of the non-conformances which were raised, found to be compliant with AS 9100B:2004 and ISO 9001:2008 standards. The audit details were not included in this document because of their confidentiality. The documentation system satisfies the applicable regulatory authority requirements.

Recommendation of the Certification Body

A process-based audit has been conducted by the CB at the research partner as their second surveillance audit. The conformance to the requirements and objectives of AS 9100B:2004 and ISO 9001:2008 was determined. The methods which the CB used to

determine this conformance were: the conducting of interviews, observations, sampling of activities and a review of documentation and records.

Conclusion and Validation of QMS

"The audit team concludes that the organisation has established and maintained its management system in line with the requirements of AS 9100B:2004 and ISO9001:2008 and demonstrated the ability of the system to achieve requirements for products and services within the scope and the organisation's policy and objectives.

Therefore the audit team recommends that, based on the results of this audit and the system's demonstrated state of development and maturity, that this management system continues to be certificated to AS 9100B:2004 and ISO9001:2008" (Bureau Veritas Audit Team 12-05-2010).

7.3 Validation through observation of a similar case study in Sweden

Background to the Case Study in Sweden in Collaboration with Volvo Aero Company:

The emphasis on safety and quality in the airline industry, as well as the whole aviation industry, is extremely high. As a consequence, the suppliers who supply products are permanently under control. Volvo Aero currently manufactures parts of an aircraft engine and in its production partly depends on customer demand for its products as well as the quality of its subcontractors. To become a supplier of parts for an aircraft engine requires the approval of both authorities and engine manufacturers.

The tough requirements have led to a static range of supplier companies that specialise in their field. Today there are three major aircraft engine manufacturers or OEMs (Original Equipment Manufacturer) that assemble complete engines for aircraft with more than 100 seats; these are GE, Rolls-Royce and Pratt & Whitney. Each OEM has its own supplier base that can be used to manufacture parts for its engines. In addition, they have their own quality systems and standards apart from the subcontractors.

Volvo Aero manufactures specialised components for aircraft and rocket engines. It is a first- or second-level supplier for all three OEMs. The goal is for OEMs to purchase from fewer suppliers and larger, pre-engineered systems. This development has the effect that Volvo Aero is increasingly being entrusted with the power to control and classify their own subcontractors, in the supply chain (Johansson, Stenmark 2005).

Problem Definition

The risk presented by the self-approval of contractors is that there may be a failure in the production of the product that can result in an aircraft accident involving fatalities. Quality controls are therefore extremely important and the knowledge and skills that authorisation personnel require, need to be validated and secured. This requires a comprehensive or multi-step system that can verify that the authorisation is made in a legally secure and reliable manner.

The overall purpose is to establish support efforts to assist the suppliers with AS 9100 certification, by narrowing the gap that these suppliers still may have to conform to this Standard. This may assist Volvo Aero to build its own local supplier base and will shorten the lead time it takes to wait for material if it must be shipped from elsewhere. The goal is to make it easier for new suppliers to start producing and supplying components for the aerospace industry.

Volvo Aero's goal is to develop and ensure the quality of a system that would approve new suppliers meeting the AS 9100 requirements. It wants to develop quality procedures and systems for the approval of new subcontractors. After giving guidance to these companies, they will be able to apply for certification. The quality of the suppliers' QMS is intended to be such that they will conform to the requirements and would not experience difficulties to become certified.

The subcontractors' goal is to achieve a fast and efficient production shift to become an approved supplier to the aviation industry by creating procedures and quality systems for production conversion. In this way, they will develop valuable skills as an integral part of the conversion process that are appropriate for exploiting new business opportunities. Another goal is to investigate the flexible and IT-based learning system that can help to streamline and support the processes required to become qualified and approved suppliers to the aerospace industry.

The project is based on Volvo Aero's need to broaden and develop its network of subcontractors for the production and delivery of parts for aircraft engines. Currently there are only a few approved suppliers to Volvo Aero in reasonable proximity to the company's manufacturing facility. There is therefore a drive in the company to explore the possibilities that they, as a player in the supply chain with newly allocated authority, can establish SMEs in Sweden to develop their own quality management systems that will comply with AS 9100 and become AS 9100 certified subcontractors.

Observing the Case Study

Several manufacturing companies in the region of Västra Götaland have been identified as potential suppliers to enter the aviation industry. Given the current global economic crisis, SMEs will be positive to accept the new challenges and requirements in order to generate more income. The production of parts for the aerospace industry may be a possible solution for them to stay in business and increase their customer base in the long run.

A company was identified to serve as the pilot company to track the process. They contracted a consultant to do the QMS design, development and implementation. It was observed and served as a case study to help design and develop a generic process that more companies can use to help them reach the AS 9100 level of quality and obtain certification as an end goal.

The objective of observing this project was to determine whether the process that was followed at the case study of the research partner (Daliff) correlates with the process in Sweden and may be used in further research for them as well as in South Africa.

The SME under observation was also a manufacturer of small parts, but did not have certification to supply products to the aerospace industry. Volvo Aero Company identified them as a pilot company because they had used them in the past to manufacture prototypes and was satisfied with the results.

Findings:

The process which the consultant followed was based on the same sequence of activities that were executed in the case study at Daliff. The sequence was:

The process was initiated by means of an opening meeting in which they described their work procedure (the observation is illustrated in figure 38) as a consultant:

Analysis of the as-is status of the company (Gap Analysis)

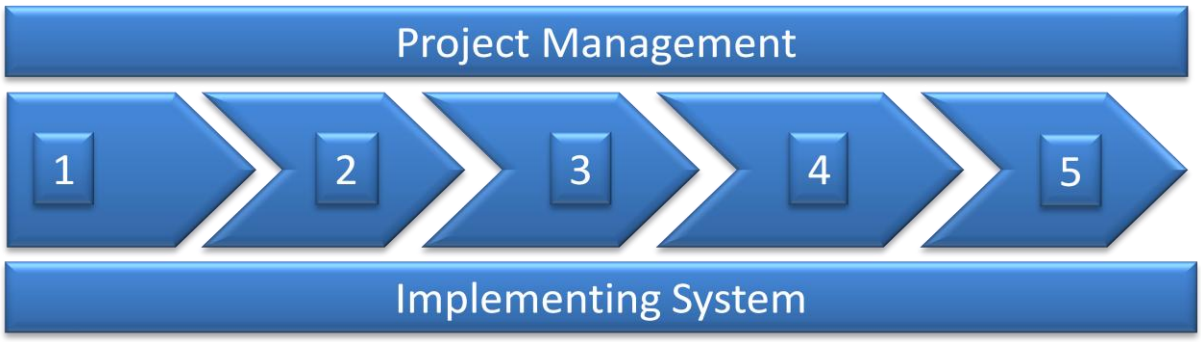

Figure 38: Implementation plan of Design, Development and Constructing of QMS (observation of Consultant's process)

1. Determining of main process
2. Map and interface the main processes and sub-processes while assigning responsibilities to the different levels of the processes
3. Define targets and objectives for the processes
4. Building the system to achieve the targets
5. Continual improvement and maintenance

The process was compared to the process described in Chapter 6 and found to be adequate if applied at other SMEs. The obstacles which SMEs face in Sweden do not differ to a great extent from these in South Africa. In general they can learn from each other and share experiences in overcoming obstacles.

7.4 Generic Plan in Implementing AS 9100 QMS:

After the conducting of this case study, the steps that a business needs to take in order to design and develop an AS 9100 IT-based QMS can be summed up in figure 40. This overview, in collaboration with the specific requirements of the standard and the guidelines

described in the design and development chapter (Chapter 6) will assist organisations (specifically SMEs) to become AS 9100 accredited.

The whole process starts with recognising the importance of your customer's requirements. These requirements need to be fully understood in order to be reached. The processes needed to achieve these requirements must be documented. It is important to do what you say your organisation does and to have proof thereof. The importance of documentation, authority and traceability is what distinguishes the aerospace industry from other industries. Continual improvement of the entire system is an ongoing process which may follow the Hoshin Kanri model of thinking. The cycle of action research does not end here; it is an ongoing process which will always be evaluated, reviewed and continually improved if managed effectively. The specifying learning (highlighted in figure 39) will contribute to the continuous monitoring and improvement of the client system (in this case the research partner's QMS)

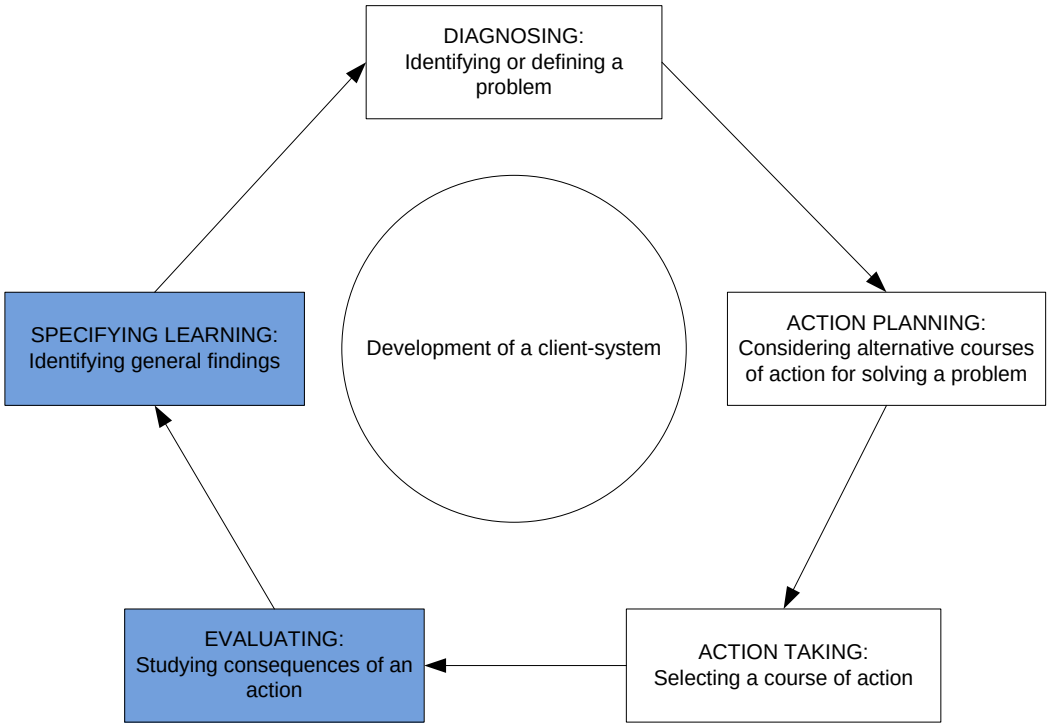

Figure 39 The cyclical process of action research (Susman 1978)

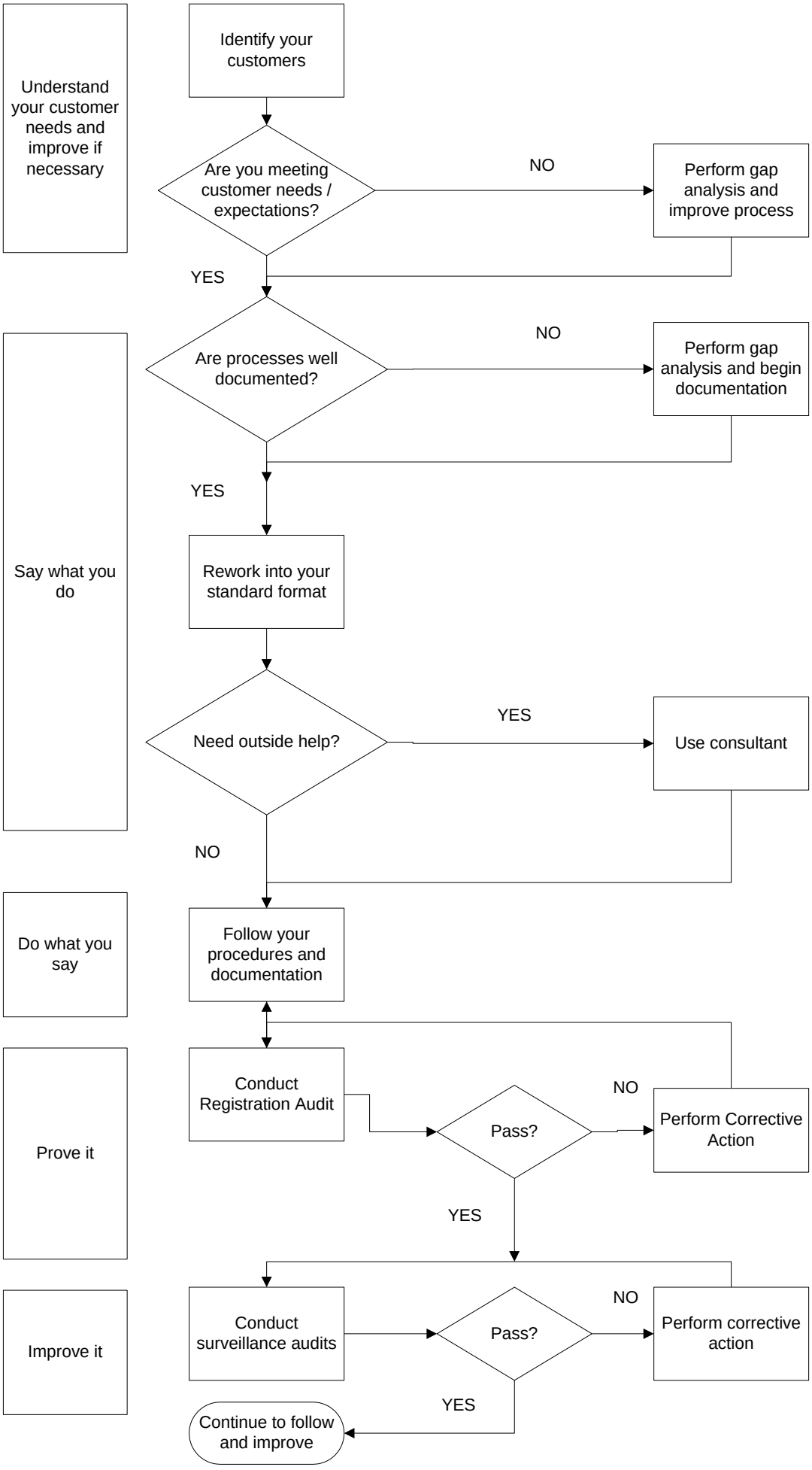

Figure 40: Overview of the Generic Steps to Certification (Myhrberg,E.V. 2006)

8. Conclusions, Limitations and Recommendations

Conclusion

In spite of the economic crisis that the world faced recently and still struggles to overcome, the South African aerospace sector is growing rapidly. Before the recession SME's did not see the necessity to apply for international quality accreditation such as the standard under discussion, AS 9100. The difficult business conditions created a sense of urgency for them to become accredited. They realise the importance of accreditation as an order qualifier. The investigation of a method to overcome the lack of knowledge about the Standard and other difficulties SME's may face, have been conducted. The result was the design and development of an IT-based AS 9100 quality management system at a SME in the aerospace industry and a successful implementation therof. The steps that were followed to implement this upgrade of the QMS and its generic value were investigated by means of internal and external audits as well as observations of the same implementations at SME's entering the aerospace industry in Sweden. The SME that served as the research partner is a manufacturer of small aerospace parts as a tier three supplier in the Airbus Industry and Boeing supply chain.

The steps that were followed to implement this upgrade of the QMS and its generic value were investigated by means of internal and external audits as well as observations of the same implementations at SMEs entering the aerospace industry in Sweden. The SME which served as the research partner is a manufacturer of small aerospace parts and a tier-three supplier in the Airbus Industry and Boeing supply chain.

The obstacles which SMEs face can be overcome. The study guides them to a better understanding of the quality management standard, AS 9100 and its requirements. The implementation process that was followed was validated to determine its generic value and found to be applicable to more than one country.

The IT implementation of the system reduces the administrative cost and ensures the effective execution of the procedures by means of continuous monitoring and measurement thereof. The system accommodates configuration management of all the applicable areas.

After the case study has been conducted and the validation process executed and finalised, the author concludes that the investigation may serve as a guideline for SMEs when designing, developing and implementing an AS 9100 IT-based QMS. It should not be seen as a set of rules to follow but can be used as a basic framework for their AS 9100 certification plan.

Limitations and Recommendations:

Limitations identified during this study

Companies (SME's) lack knowledge and vision for AS 9100

The size of a small to medium sized enterprise makes it difficult to assign responsibilities to employees in specific areas or departments. The reason for this is that the workforce may rotate and employees rotate between departments as required. The quality education therefore gets shifted to a lower rank on the list of priorities and in the long term has a negative effect on the business. A quality mindset needs to be formed right from the start of a process up to the final product and irrespective of the position of an employee.

The lack of knowledge and resources of SMEs need not necessarily be a stumbling block for entering the aerospace industry. The gap between their as-is state and the state of a certified company can be bridged and continually improved by this implementation plan.

The research partner does not perform:

- special processes (Clause 7.5.2)
- design and development activities (Clause 7.3)

Research can be extended into these areas.

Recommendations:

i. Training in AS9100 /

Workshops for SME's aspiring to enter the aerospace industry and are not certain exactly what is expected from them to acquire certification, is identified as useful. Funding can be applied for from government funding bodies such as DST and DTI. These workshops can be in the form of a training day by AS 9100 consultants to educate and broaden the companies' knowledge about the standard and help them to recognise their current quality status and present them with enough information to determine the possibility to narrow the gap between that and the required standard which they have to comply with. An AS 9100 training day should educate the SME enough to make a valid decision whether or not it is the right time for them to start to prepare themselves for certification or if the gap is still too large to first make some adjustments to their business processes before applying for AS 9100 accreditation.

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10. APPENDIX A

10.1 Checklist for References of the Functional Areas to the AS 9100 Standard

Checklist for References of the Functional Areas to the AS 9100 Standard

10.2 First Internal Audit Program

Table 16: Internal Audit 1 Program (Appendix A)

No	Procedure Name	Auditor	Stamp	Auditee/Process Owner	Stamp	Day 1	Day 2	Day 3	Day 4
1	Management Review			Management Rep					
2	Contract Review			Management Rep / Production Manager					
3	Control of Records, Documents and Soft stamps (Including Configuration Management)			Management Rep					
4	Purchasing			Buyer					
5	Control of Customer-Supplied Product			Buyer					
6	Process Control (Including Configuration Management)			Production Manager					
7	Inspection and Testing			Quality Manager					
8	Control of Inspection, Measuring and Test Equipment			QC Dept					
9	Inspection and Test Status			Production Manager / Buyer / QC Dept					
10	Control of Non-conforming Product			Quality Manager					
11	Corrective and Preventive Action			Quality Manager					
12	Handling, Storage, Packaging, Preservation and Delivery								
13	Internal Quality Audits								
14	Training								

10.3 Second Internal Audit Program

First Internal Audit Program

Table 17: Internal Audit 2 Program (Appendix A)

No	Procedure Name	Auditor	Stamp	Auditee/Process Owner	Stamp	Day 1	Day 2	Day 3	Day 4
1	Top Management			Management Rep					
2	Quality Management			Management Rep / Production Manager					
3	Human Resources			Production Manager					
4	Configuration Management			Management Rep / Engineering Dept / Buyer					
5	Marketing & Sales			Management Rep / Engineering Dept / Buyer					
6	NC Programming			CNC Programmer					
7	Procurement / Purchasing			Buyer					
8	Calibration (Monitoring & Measuring Equipment)			QC Dept					
9	Manufacturing			Production Manager / Buyer / QC Dept					
10	Machines & Tooling			Production Manager / Storeman					
11	S.H.E			Production Manager					

10.4 Example of Turtle Diagram in the Process Analysis step

Example of Turtle Diagram in the Process Analysis step

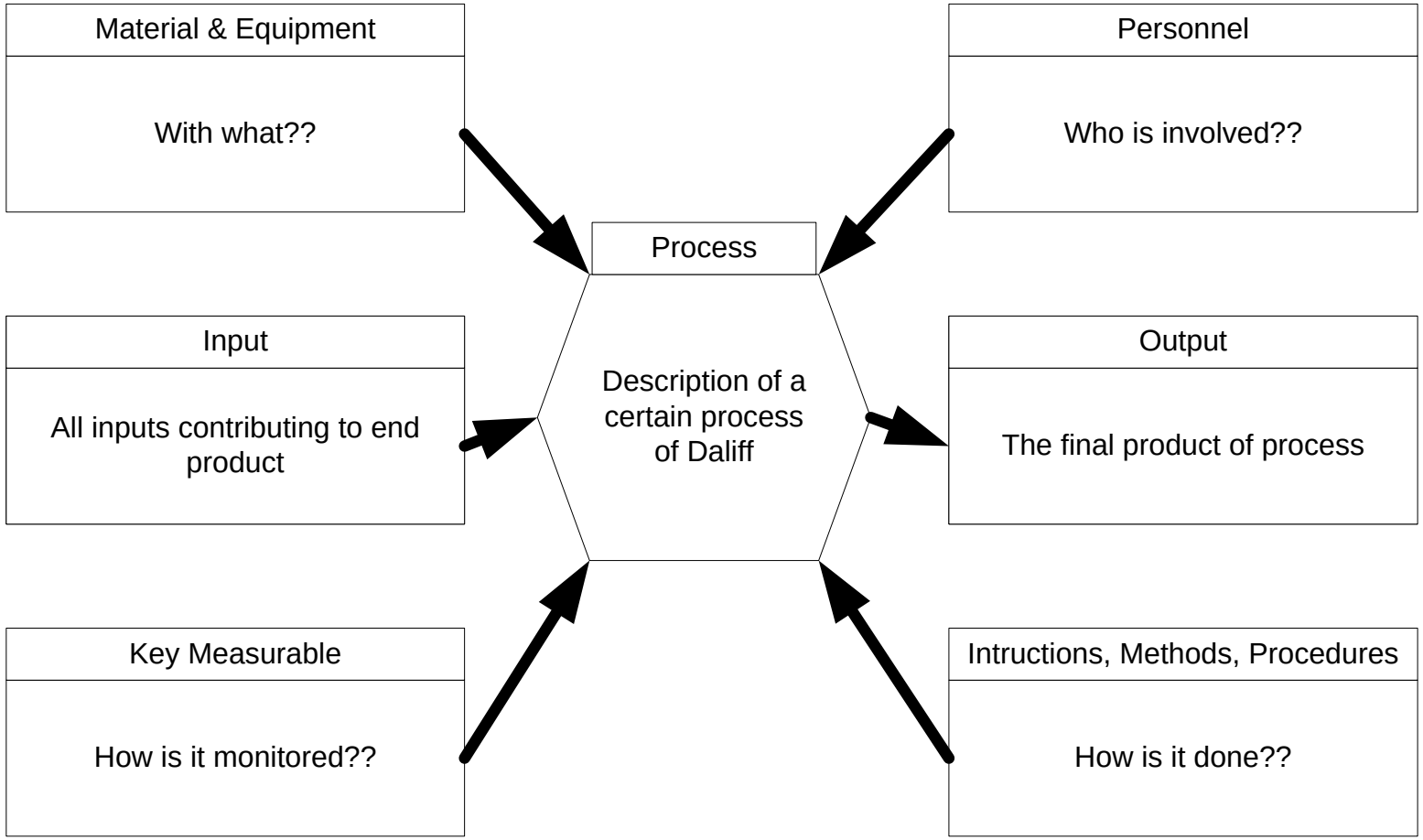

Figure 41: Example of Turtle Diagram in the Process Analysis Steps (Appendix A)

10.5 Flow diagram for the Duration of Quality Assurance Project (Case Study)

Flow diagram for the Duration of Quality Assurance Project (Case Study)

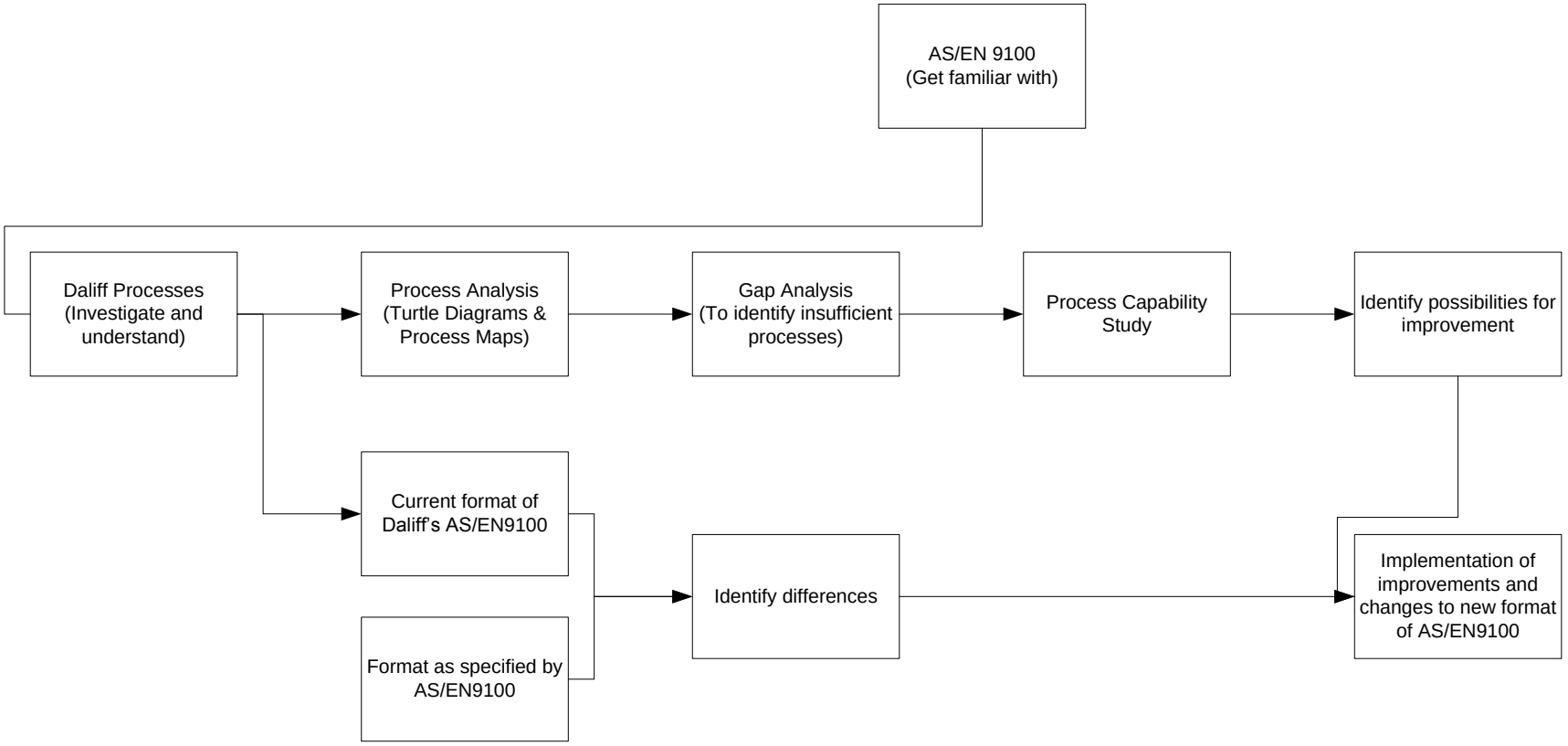

Figure 42: Flow diagram for the duration of Quality Assurance Project at the Research Partner (Appendix A)

11. APPENDIX B

11.1 IDEF0 Model of the Research Partner / Generic for other Aerospace Companies

12. APPENDIX C

12.1 The Research Partner's Quality Management System (Confidential)

(Permission to view this Appendix must be asked from the Library/Author)

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