

**INSTITUTO TECNOLÓGICO Y DE ESTUDIOS  
SUPERIORES DE MONTERREY**

**CAMPUS MONTERREY**

**ESCUELA DE GRADUADOS EN ADMINISTRACION  
Y DIRECCION DE EMPRESAS**



**TECNOLÓGICO  
DE MONTERREY.**

**FRAMEWORK FOR THE QUALIFICATION OF  
MEXICAN SMEs AS SUPPLIERS IN THE  
AEROSPACE SUPPLY CHAIN**

**TESIS**

**PRESENTADA COMO REQUISITO PARCIAL PARA  
OBTENER EL GRADO ACADÉMICO DE**

**MAESTRO EN DIRECCION PARA LA MANUFACTURA**

**POR:**

**LUIS DAVID GAMBOA BECERRA**

**MONTERREY, N. L., MEXICO**

**ABRIL DE 2008**

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## CHAPTER 1

### 1. INTRODUCTION

The Mexican aerospace metalworking industry started its development a few years ago when Tier 1 suppliers arrived in different regions of Mexico. Aerospace Original Equipment Manufacturers (OEMs) and Tier 1 suppliers (see figure 2-3) need to have a capable and reliable supply chain to achieve their goals, complete their production forecasts and get profits for their major investors in Mexico. To do this, companies need to increase the size of the supply base to take advantage of the low production cost, especially for labor-intensive production and services (Moghamad and Crawford, 2007). It is convenient for OEMs to have Mexican suppliers. By doing so, they can reduce cycle times and costs by means of buying parts locally and assembling their products faster. They are also trying to have more flexibility to choose between supply sources, whether internal or external, to have their sources of intermediate products closer to sources of sub-products (sub-assemblies) and raw materials. Also, OEMs want to be able to focus on the core competencies to be developed in Mexico. Long term suppliers are required in every aspect of the supply chain. However, it takes a lot of time and investment to develop long lasting partnerships, but there is a real opportunity for Mexican companies.

On the other hand, nowadays there are three levels of Mexican Small and Medium Enterprises (SMEs) on the map (without including foreign companies' extensions): a) interested potential suppliers, b) a small number of actual initial suppliers which are already providing some parts, and c) a smaller number of consolidated suppliers. Tier 1 companies have invested money to make suppliers follow their requirements. They've started supplier development programs with Mexican companies in order to help them become aerospace qualified companies with quality accreditations, business skills and the needed equipment to execute the assigned jobs. Only a few Mexican companies have been developed, and now they are facing common issues, such as, legal differences and import duties of materials and equipment, dealing with a foreign industry culture, quality certification issues, technical and managerial skills to be achieved, and the dependence on independent suppliers and decreased ability to keep abreast of emerging technical requirements (Amado, 2007).

Supply Chain Development (SCD) is recognized as a key towards developing a competitive edge in the global marketplace by increasing supplier performance and capabilities to meet the buying firm's short and long-term supply needs (Krause and Ellram, 1997). Today, product developers face an increasing challenge in dealing with key partners and suppliers who have a significant role in the design and manufacture of their product's major subsystems. Conversely, suppliers of major components and assemblies must also coordinate their technological development, product design and manufacturing efforts with companies that integrate the product (Reed and Walsh, 2002). As these partnerships become increasingly globalized, managing multiple suppliers across the supply chain becomes the key element in accelerating development and production cycles enhancing product and process quality. This and other reasons like the certification of processes, the capabilities of the different Tiers, suppliers, etc., represent important issues for developing an aerospace supply chain. Many aerospace companies have or are interested in establishing operations in Mexico to take advantage of the lower cost structure (Friedman, 2006). The development of qualified suppliers is a significant challenge which puts their operations at risk.

The metalworking Mexican SMEs that belong to automotive clusters are very competitive, producing high volume parts with an intermediate to high complexity, where for the most part, they use conventional methods with low levels of technology and engineering. Many of these same companies want to become suppliers to the aerospace industry; however, there is a lack of the necessary capability in technical and business areas. The aerospace industry has been establishing itself in México. The industry needs to grow faster, but it is hampered by the rate of qualification of metalworking manufacturer suppliers.

This document presents an investigation of the actual qualification process followed by different aerospace customers and how actual suppliers have obtained a certification status. This is to bring a better plan to develop aerospace suppliers in México. Specifically, the investigation studies existing aerospace supply chains and potential suppliers to the aerospace industry in Mexico, and develops tactics of how to best qualify suppliers in Mexico given the requirements of aerospace OEMs, the state of Mexican companies as well as the Mexican business environment. The results of this study will allow Mexican companies to be

qualified as aerospace suppliers with a shorter ramp-up time when manufacturing metalworking components, as well as less expense from aerospace companies to develop a qualified supply chain. It implies that suppliers must get the common set of certifications required by aerospace customers such as the AS9100B Quality Management System (QSM) and Nadcap certification for special processes practiced by suppliers.

At the moment, Mexican SMEs which want to start in the aerospace business have critical questions about the investment and time that it takes to be an aerospace supplier (Friedman, 2007). The report will serve future and present aerospace suppliers: 1) to know the best procedure whereby Mexican SMEs can become qualified aerospace suppliers, 2) to let them know the supplier selection and qualification processes that OEMs and Tier 1 aerospace companies commonly follow to pick a supplier and the requirements needed by different areas of the organization, 3) to let them estimate the time and money needed to become aerospace suppliers, 4) to define, illustrate, and explain the quality requirements for prime and sub-tier suppliers and processors on product purchased for production regarding metalworking, 5) to define, illustrate, and explain the requirements for suppliers to achieve certification status, which is needed to facilitate long term business opportunities with aerospace Tier 1s and OEMs. This study will also serve aerospace OEMs and Tier 1 companies: 1) to identify what companies are real candidates to be aerospace suppliers, which will save time during the supplier qualification process, 2) to identify potential suppliers that can exactly fit the production and capacity according to the business need, 3) to identify the common performance gaps that Mexican companies need to close. This will motivate aerospace companies to implement supplier development plans, and government to create efficient support programs.

## **1.1 Background**

Mature and increasingly saturated markets are pressing companies in developed markets to compete more on cost. These price reductions or cost downs are passed through the supply chain. Outsourcing (subcontracting a process, such as product design, manufacturing...etc., to a third-party company) to low cost countries (LCC) is one of the most common ways to reduce the cost of operation. The rate of outsourcing has steadily increased over the past 50 years and if the current trend is an indication, many experts believe that it will continue to

grow. A study of contract manufacturing trends found that 92% of companies in USA outsourced some of their production; with 40% projecting they will outsource more in the next two years (AMR Research, 2007). Outsourcing low productive and labour intensive operations which are not easily automated continues its momentum in the future.

Within the industry at the world-wide level, the aerospace sector occupies a predominant place due to the high technological and economic advance that it implies. The aerospace industry at the moment is one of the most high technology activities in advanced countries. The four main world-wide level civil airplane producers are Airbus and Boeing (big airplanes) as well as Bombardier and Embraer (regional airplanes). These companies are the main OEM customers along the aerospace supply chain which demand jobs for parts, components, sub-assemblies, sub-systems, complete assemblies and complete systems for their different aircrafts or final products (Niosi and Zhegu, 2005). With the intention of reducing their costs, the aerospace OEMs have looked for other companies in LCC, such as México, that can make partial subassemblies (motor, structures, undercarriage and electronics), and these companies are concentrating on their design, assembly and aircraft commercialization capacities (Reed and Walsh, 2002). Likewise, efforts are being made to reduce, to reorganize and to optimize their own suppliers.

According to the Federal Aviation Administration Aerospace forecast, the United States is the main aerospace technology producer, as well as the most important market for the aviation industry (FAA, 2006). The constant and strong expansion of the economy are a good omen for the United States civil aviation industry. The forecasts for the period 2007-2017 consider that the expansion of the American economy remains strong (FAA, 2006). According to the projections, the long term economy growth will be greater in Mexico/Latin America and Asia/Pacific regions, growing in 3,8 and 3,6 percent, respectively during the 2007-2008 period (FAA, 2006).

At the moment, the support of the federal government to the aerospace industry in Mexico is growing. Federal authorities have been attracting more investments to fortify the technological advance, and foreign OEM/Tier 1 companies have been increasingly installing manufacturing facilities in Mexico (see appendix III).

The Aerospace Industry in Mexico forecast is optimistic and challenging. Within five years Mexico could be able to manufacture complete commercial airplanes. In addition, in three to five years Mexico could also become a small planes manufacturer for the export market. According to the Federal Government (Mexican Republic Presidency, webpage) there are three stages for the development of the aerospace sector in Mexico, of which Mexico is now at the second one: 1) to consolidate the present manufacturing and engineering capabilities, 2) to initiate a more complex manufacture of parts and components and structures, 3) to completely assemble an airplane in Mexico in the medium term. In this industry, Mexico is facing the competition of nations like Brazil, which has built its development around the Embraer Company, the fourth worldwide aircraft manufacturer. For these and other reasons, like the proximity to North America, Mexico is fundamental for OEMs and is appearing to the world like a country which is not only attractive for manufacturing in the short term, but also can climb the value chain by developing design capability, and attract business in the medium and long term. The development of this industry requires support and joint strategies by three fundamental sectors: private organizations, government and education institutions.

This thesis came to be due to the need of around 20 SMEs, the government and the ITESM in the state of Nuevo León, México, which are concerned about the growth of this industry in Mexico. Some of these companies want to become aerospace suppliers in the near future. They want to build an aerospace supply chain in Mexico and agree that it is a big challenge to be accomplished. There is an immense opportunity for those Mexican SMEs which are now working in several other industries (automotive, packaged and goods, lighting, etc.). The manufacturing and assembly of the complex parts that are labor intensive represent a good opportunity for Mexican companies, given the nature of the industry, which has low automation in the assembly processes. There is a market opportunity principally in part production that implies machining jobs and different special processes (Diaz, 2007).

This study has been made as a collaboration among McGill University, ITESM campus Monterrey and principally with an OEM which has opened a plant in Mexico, which wishes to develop qualified suppliers in the country, and which will greatly profit from this study. Others OEMs, Tier 1s, that are actual and potential suppliers from North America have greatly

cooperated with information to build this document.

## **1.2 Problem Definition**

When OEM and Tier 1 companies find metalworking manufacturing contractors of parts, components and structures in Mexico, they begin by asking quotations of SMEs, from other industries, that want to become aerospace suppliers and which are trying to find opportunities doing jobs for these customers. Problems arise when these companies are not really capable of doing it. During the qualification process they find difficulties about requirements, certifications, managerial and technical skills, experience, delivery times, and others problems related to the nature of the industry itself. It results in time and money lost by the customers trying to contract these Mexican companies, which in many cases fail during the procurement process by not meeting customer expectations. There is a lack of availability, understanding and standardization about the aerospace industry characteristics, qualifications, supplier evaluation and selection processes, and there is significant cost and time required to become an aerospace supplier. Many Mexican companies are hesitating to make the commitment.

## **1.3 Aims and Objectives**

This thesis aims to define a framework with a set of mechanisms whereby Mexican companies can become qualified suppliers to the aerospace industry. This thesis focuses on showing SMEs an effective qualification process to meet aerospace customer requirements with the purpose of promoting supplier development in the Mexican aerospace industry. The effectiveness of certain framework stages haven't been still proved in Mexico, nevertheless, it's expected to be as effective as in North America.

In order to achieve these aims, the main objectives of the thesis are as follows:

- To define a picture of the present aerospace environment and to provide it to Mexican Small and Medium Enterprises (SMEs), showing the principal aerospace OEM/Tier 1 manufacture requirements in the qualification process for the short and long term.
- To provide small and medium sized Mexican companies with a framework that will expedite their development as qualified aerospace suppliers by letting them know the actions, estimate the time and money each one needs to invest during the process.

- To determine the best practices in the aerospace industry for supplier qualification and the processes whereby aerospace companies (OEM and Tier1s) qualify and develop their suppliers.
- To create a diagnostic tool (self-assessment) by which Mexican SMEs can assess and establish their readiness in order to become aerospace qualified suppliers.

## **1.4 Scope**

The study is focused on improving the planning of the supplier development process; therefore, future suppliers will be able to obtain the qualifications faster and at lower cost. There are other different aspects in the aerospace supplier development where companies need to work in (such as financial, and technological). The scope of this study is mainly focused on the managerial side, which involves the quality management system, procurement, manufacturing, logistics, and infrastructure. The main contribution of this thesis is the framework that is to serve as a diagnostic to detect the opportunity areas for actual metalworking Mexican SMEs and the gaps that need to be closed in order to achieve an aerospace supplier status according to the common set of certifications required by aerospace customers, such as the AS9100B Quality Management System (QSM) and Nadcap certification for special processes practiced by suppliers. This study is not about supplier development, it is focused on a previous stage, where a company needs to know the requirements, its actual state compared with other qualified suppliers/customers, and the feasibility of beginning the qualification process. It would let them estimate time and other costs that will take to become a qualified aerospace supplier; however, these two variables are relative and depend on the specific situation of each company.

This study is concentrated on small and medium sized companies in the metalworking sector in northeast México. However, the results of the study apply to companies elsewhere in México.

## **1.5 Project Justification**

As remarked before, aerospace OEMs have moved to Mexico to take advantage of lower cost structures. The OEMs have found that there are only a few qualified suppliers in several areas. Although Mexican companies are qualified suppliers in the automotive, electronics,

consumer/packaged goods and others sectors, these capabilities are not sufficient to qualify as an aerospace supplier. Mexican aeronautic industry is demanding specialized training in technology skills, laboratory tests (mechanic, chemical), manufacture processes advisory (optimization) and norms assistance. In addition, the companies do not have sufficient experience with required contracting and business procedures used in the aerospace sector. Information services about norms and technological articles are currently being provided principally by costumers, then internet sources, corporative and finally suppliers (Diaz, 2007).

Today raw materials and components are mostly being imported from US. The actual Mexican products acquired are in general auxiliary materials such as: gases, diverse pickings, supports, paper, abrasives, and chemicals. The aerospace Mexican supply interest is high; some companies want to acquire products from Mexico, and today the principal opportunities are for basic materials and finishes, processes and components, accessories, auxiliary materials, structural parts (machining, sheet metal, etc.) and others (Diaz, 2007 and Friedman, 2006). Most of the companies wish to have local incomes, principally for CNC jobs, finished surfaces, welding jobs and for materials such as aluminum, glass fibber, carbon fibber, and others. To convert companies and prepare them to be aerospace suppliers is needed to get the certifications required and quality standards with the aim of begin producing for the existing customers in the local country and outside of Mexico.

The development and application of the qualification framework in the aerospace sector is unique and have shown the value of the approach. There are other aerospace research works about supplier development with models of organizational development by introducing quality practices to SMEs, as report of (Rodriguez-Carral, 2006) and another example found on (Reed and Walsh, 2002), which seeks to enhance the technological capability through supplier development by transferring best practices in product development, the similarity between these and the presented work is in aiming to help developing a aerospace supply chain in a country. However, the focus of this paper is not to enhance supply chain performance through improved visibility with actual suppliers as example found on (Bartlett et al., 2007). An intention of this thesis is to detect the most critical evaluation factors considered by aerospace customers, similarly to (Bartlett et al., 2007). In a similar manner to (Mendes Primo et al., 2007) the thesis presented here contributes to inform SMEs about the



customer prime requirements and aerospace customers' reactions to supplier failure and recovery.

## **1.6 Structure of the Thesis**

Chapter 1 portrays the tasks of this research thesis, includes the background and justification for this research work, as well as aims, objectives and scope.

Chapter 2 is a compilation of the literature review, describing concepts already in the state of the art and used for this thesis development.

Chapter 3 provides the main proposal of this thesis, a framework that will guide companies on how to become qualified aerospace suppliers and a self-assessment tool derived from it.

Chapter 4 presents a Case Study which validates the framework and self-assessment tool proposed in Chapter 3.

Chapter 5 discusses results obtained from the implementation of the Case Study, as well as conclusions drawn. Finally, some recommendations for further research are described.

---

## CHAPTER 2

### 2. LITERATURE REVIEW

As described in Chapter 1, this research deals with proposing a framework with actual methodologies, techniques and mechanisms that will serve to prepare SMEs in order to help them to establish their opportunity areas and readiness to meet aerospace customer requirements. Based on previous research considered as Background and the Objectives of this work, it is required to describe the elements that will be taken into account to build this thesis proposal.

This section presents a review of the main concepts relevant to the thesis, which serves as a basis for outlining the elements of the presented framework and its application by a self-assessment tool. This chapter deals with the following subjects:

-Description of SCM (supply chain management) in the Aerospace Industry, understanding its main characteristics, the Tiers' structure and its productive value chain. This section also explains the relationship with the supplier selection in the aerospace Supply Chain (SC) and its development evolution training suppliers.

-Best quality practices: This section portrays the basic, detailed supplier requirements, which are needed to get standardization. It contains useful information about the certifications used in this industry, their principal benefits, advantages and principal differences compared with more basic others. The review of the mainstream best quality practices help to build a path to become aerospace supplier in this thesis.

-Aerospace supplier certification and qualification mechanisms: The last section of the literature describes the supplier certification methods and evaluation processes according the research done, and the supplier selection techniques, schemas and tests used by big aerospace companies. This section also reviews the performance and supplier evaluation processes by means of which aerospace customers (OEM/Tier 1s) monitor and control vertically the SC. It is important for suppliers to determine the key areas where they need to focus. Also an example of how customers measure the supplier risk in aerospace industry is shown. Some actual supplier development (SD) practices are listed to understand their

important role in SCM, the actual practices that companies use to develop and to prepare their suppliers in order to achieve their production goals, and how SMEs can improve their processes. Finally, this section describes standard supplier selection methods, as currently used by prime aerospace customers.

All these concepts will be further implemented in Chapter 3 as part of the original proposal of this thesis. Based on the previous topics, a framework has been constructed to explain the supplier requirements, processes and techniques used by customers to identify, evaluate, measure, develop and approve the supplier in a qualification process. From the framework based on the research done is derived an assessment tool which will be implemented in chapter 4.

## **2.1 Supply Chain Management**

Supply Chain Management (SCM) is a continuously evolving management philosophy that seeks to unify the collective productive competencies and resources of the business functions found both within the enterprise and outside in the firm's allied business partners located along intersecting supply channels into a highly competitive, customer-enriching supply system focused on developing innovative solutions and synchronizing the flow of market place products, services, and information to create unique, individualized sources of customer value (Ross, 1998). In this age of outsourcing ("putting out" of non-core internal processes), organizations and their SCs are actually interconnected and interdependent networks. The term supply chain is therefore used here in the sense that Christopher et al. (2002) defines it as: "the management of upstream and downstream relationships with suppliers and customers in order to create enhanced value in the final market place at less cost to the SC as a whole".

### **2.1.1 Aerospace Supply Chain Management**

The manufacturing industry has been moving away from vertically integrated companies with design, development, manufacturing, and assembly performed in-house, toward a supply network of many companies performing different functions (Reed and Walsh, 2002), and in a similar manner, the major aerospace original equipment manufacturers (OEMs) are no longer the vertically integrated companies that they once were. It is commonly quoted that suppliers

provide around 70 per cent of an OEM product (Fan et al., 2000). Suppliers fulfill different roles and have different scales of responsibilities, e.g., a systems' supplier may take full responsibility for the avionics or fuel systems of an aircraft. Strategic suppliers are likely to be those referred to as black box suppliers or subcontractors. Kaufman et al. (2000) describe a typology of small and medium sized manufacturing suppliers (see Figure 2-1), where the technology specialists and problem-solving suppliers are likely to be the most critical in terms of their contribution to the end product in the aerospace industry. The interfaces between these relationships are normally governed by technical and contractual definitions.

|            |      | Collaboration                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                                                                                             |
|------------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|            |      | Low                                                                                                                                                                                                                                                                                                   | High                                                                                                                                                                                                                                                        |
| Technology | Low  | <p><b>Commodity Supplier</b></p> <ul style="list-style-type: none"> <li>• Spot market supplier</li> <li>• Low cost, low price priorities</li> <li>• Little or no differentiation</li> </ul>                                                                                                           | <p><b>Collaboration Specialist</b></p> <ul style="list-style-type: none"> <li>• Detail-controlled parts supplier</li> <li>• Uses a closed network in each industry</li> <li>• Can be in many industries to maintain customer product information</li> </ul> |
|            | High | <p><b>Technology Specialist</b></p> <ul style="list-style-type: none"> <li>• Proprietary parts supplier</li> <li>• Innovation in product technology used to produce high barriers to entry</li> <li>• First mover advantages</li> <li>• Uses design capabilities for competitive advantage</li> </ul> | <p><b>Problem-solving Supplier</b></p> <ul style="list-style-type: none"> <li>• Black box supplier</li> <li>• High differentiation</li> <li>• Cost less important</li> <li>• Small runs, high process and labor flexibility</li> </ul>                      |

Figure 2-1. Typology of Small and Medium-sized manufacturing suppliers. Kaufman et al. (2000).

There are other suppliers which are providing manufacturing processes or material. Some of these could be machining or assembly processes that the OEMs disposed of during their downsizing exercise, which is an opportunity for Mexican SMEs and it is shown below in a schematic Aerospace SC Diagram (see Figure 2-2).

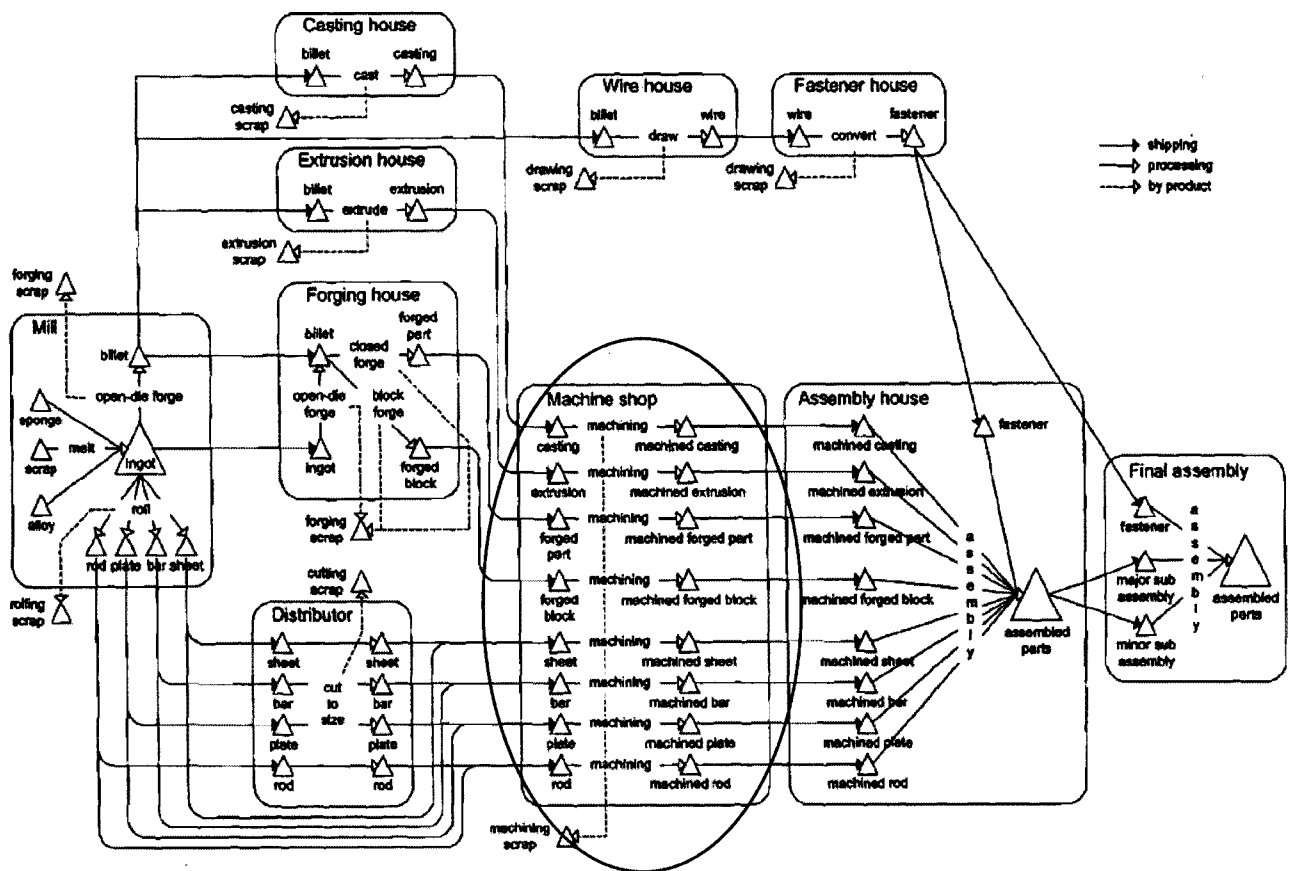


Figure 2-2. Boeing Aerospace SC schematic. Bilczo et al. (2003).

These are the “low intellectual property” jobs that are easier to transfer in any offset or supplier change scenarios. Although these are supposedly “lower” value added work, they make up a large proportion of the actual product. More importantly, if there are delays and difficulties with the production of these items, the overall delivery program will be delayed.

The outsourcing of components represents a challenge in LCCs for OEMs in making sure that the product can be manufactured as designed within the time, cost and quality budget. This is often difficult if the design team doesn’t know who is going to manufacture the part and are not certain about the manufacturing process or the manufacturing equipment.

One may argue that agreed standards of manufacture provide the guidelines needed for specifying the product for manufacture. Various in-company standards had been in practice for many years and form the basis for manufacturing approval of drawings (Fan et al., 2000). However, the amount of time and effort needed to get production right whenever any components are transferred between suppliers cast doubts on the effectiveness of these

guidelines.

In the past, aerospace OEMs had a huge force of people in certain locations, the quality departments were a medium, each one transferring the technology to the shop floor into the local side. OEMs source inspectors at that time spent a lot of time, not only doing final inspection in the technical liaison, but also they were a technical support for a lot of these suppliers, thus suppliers didn't invest more than machine time in those days (Reid, 2007). It was only in the last 20 years when they starting investing in themselves. OEMs were pushing them to do it, and they got themselves more autonomous and came out to the market as sub-tiers. Then, the companies started going into subcontracting and that was a new experience for them. So, OEMs people spent time with them to make sure, they would ask the right questions, but to do the management of the aerospace supplier base is still a challenge today.

### **2.1.2 Aerospace Supply Chain Structure**

It is important to describe the actual aerospace SC structure. The SC consists of different levels including supplier, manufacturer, distributor and consumer and is a network of companies that influence each other from raw materials to finished goods (Christopher et al., 2002; Chan, 2003). A study of OEM's supplier selection and evaluation criteria for low cost regions has been used for aeronautic structural parts. OEMs, Tier 1s, and actual aerospace suppliers from USA, Canada and Mexico have been consulted, which have cooperated in this study.

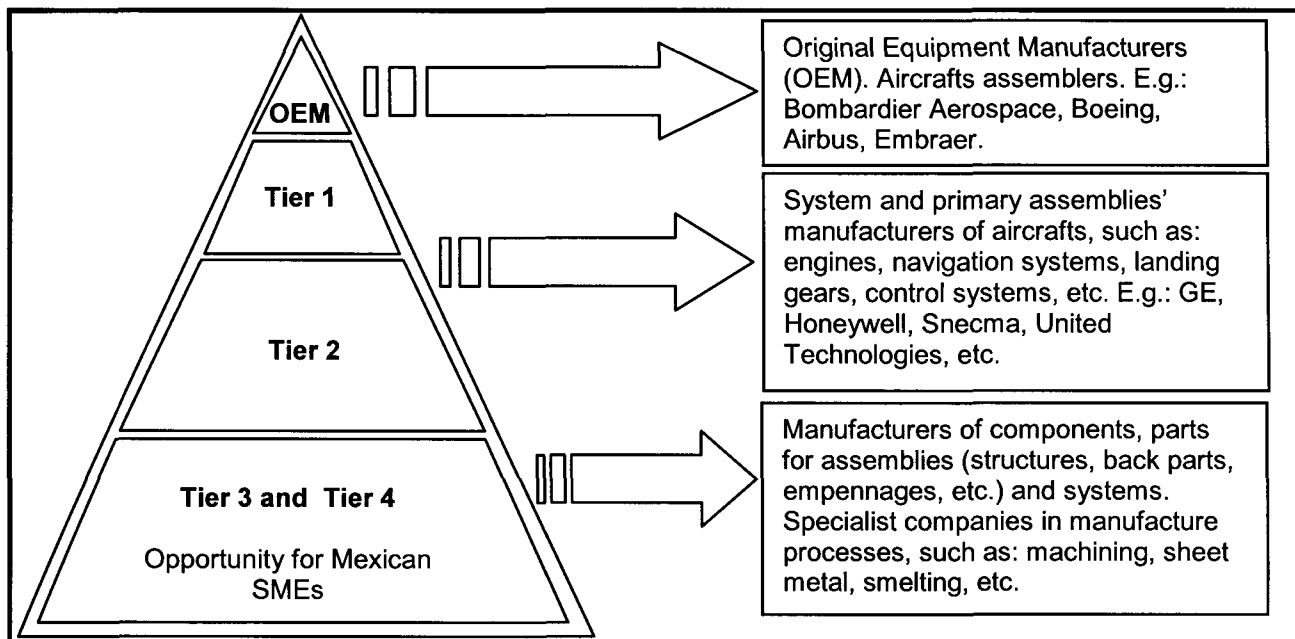


Figure 2-3. Location of the Mexican SMEs potentially integrated to the Aerospace SC Industry.

The Figure 2-3 shows the aerospace industry composition: OEMs, TIERS, SMEs. The economic concentration in the aerospace industry is very high. For each sector (international civil airplanes, regional airplanes, jets of business, helicopters, etc.) only a few competitors exist. To enter into a sector of the industry is complicated due to the great amounts of capital that is required for aircraft design and production. During this study, SMEs are referred to as potential candidates to be Tier 3 or Tier 4 suppliers of “T-3” or “T-4 in some cases; OEMs and Tier ones are referred as customers.

Tier 1 (first and second row). Classification assigned to the integrator organizations of the final product, aircrafts in this case. It is about Original Equipment Manufacturers, OEM.

Tier 2 (third row). Classification assigned to the organizations that supply systems or complete assemblies to the Original Equipment Manufacturers. Some systems or assemblies examples are: propulsion motors, auxiliary motors, landing systems, energy control systems, and navigation systems.

Tier 3 (fourth row). Classification assigned to the organizations that supply assemblies or sub-assemblies for T-2 organizations. Generally, it is about manufacturing processes in highly specialized companies. Some assemblies or sub-assemblies examples are: electrical

valves, electrical motors, gearing boxes, electrical harnesses, etc.

Tier 4 (fourth row). It is the classification that is assigned to the individual organizations that provide loose components, parts and individual spare parts that will be used by the tier two organizations.

Inside this industry, the supply chain handling is a key for the transmission of knowledge, which includes dimensions and engineering specifications, concurrent engineering, strategic alliances, control of quality, joint product development, certifications, shared delivery times, shared risks, shared costs, prices and production volumes (Niosi & Zhegu, 2005).

Some Aerospace SC trends seen in the last few years and that remain strong, according to Reed and Walsh (2002), are the following. 1) OEMs focus on core competencies and outsource more manufacturing and design. 2) Increased dependence on key suppliers of subsystems and subassemblies with an advanced product and process technology. 3) Suppliers are dependent on their customers for information for innovation. 4) There is an opportunity for large companies to utilize SD to promote better supplier technology and manufacture management practices. 5) OEMs and Tier 1 suppliers have to share their long-term needs with SMEs.

### **2.1.3 Aerospace Supply Chain Characteristics**

After defining aerospace SCM concepts and knowing its structure, it is relevant for the SMEs to understand the main aerospace SC characteristics in the next four core aspects according to this research.

a) Procurement (purchasing, quotations, and contracts): normally aerospace suppliers work with a high purchase order number variation. Their customers make formal annual customer production forecasts, and additionally, give other smaller orders during the year, which demonstrates a real commitment from the customers to reliable suppliers. In this SC, cost is usually challenged during the period approaching the signing of a “long-term agreement” (LTA). In this process, suppliers are commonly asked to bid for various packages of work, which they will then supply to the customers for an agreed price, over an agreed period of time if the bid is successful. LTAs are signed very often between partners, as



buyers and suppliers; it means that a company doing aerospace jobs can make sure that is going to work on a long term basis (García, 2007). The supplier needs a real ability to make quotations, and specially to read high complexity drawings.

b) Logistics: the common way to work is on a Make To Order (MTO) basis, where companies produce relatively low (or medium-low) volumes and have low inventories, but with a high mix of products and customers (Friedman, 2007; Amado, 2007; Nicholson, 2007).

c) Manufacturing processes: aerospace suppliers are willing to maximize their throughputs rather than minimizing their costs in comparison with other industries. It produces an increment in their prices for products, parts, components and sub-systems (García, 2007), although Bartlett et al. (2007) remark that during "last few years RR (an OEM) is focusing on achieving price reductions and year-on-year cost down performance is required of its suppliers". In general, the strategy is in high precision jobs, making high value added products for their customers. SMEs have a certain flexibility to change product specifications; for this, they need speed in the machine set up processes, which implies really good employee capabilities (Friedman, 2007). In summary, their strategy is on high precision and quality, delivery on time, low volume and continuous improvement (Reid, 2007).

d) Quality system: the aerospace industry has a very strict SC control, where each supplier needs customer approvals. The constant procurement, purchasing and performance monitoring is pretty usual between firms, and that's why aerospace suppliers constantly perform internal audits to control the non-conformance product by the use of labs, tests, etc. An example of this is the First Article Inspection (FAI), which is further detailed later in this document (Chambers et al., 2007; Reid, 2007). There is a high emphasis on traceability, according certain documentation rules defined In the Quality Management System (QMS), which is composed of the next three key areas (Hajibrahim, 2007):

-*Personnel*: must be skilled, motivated, well managed and trained with a clear understanding of what to do and how to do it.

-*Processes*: all activities that affect quality must be properly planned, controlled, evaluated, and improved when possible to achieve the requirements.

-*System*: there must be well defined and documented policies, objectives, organizational structure, resources, responsibilities and processes.

After this section the actual aerospace SC, its structure, some trends, main characteristics it are identified as well as the challenge SMEs are facing to become suppliers in this industry.

## **2.2 Quality Management System, QMS**

With increasingly competitive global marketplaces, manufacturing companies are seeking ways to sustain their competitiveness. Manufacturers need to manage their suppliers and search for an improved way to rectify any managerial deficiencies (Humphreys et al., 2001; Yeung and Chin, 2004). Managing supplier quality (MSQ) is concerned with the sourcing, evaluation and selection of suppliers, provision of education and training, monitoring of supplier performance, and supplier certification (Yeung and Chin, 2004). Trent and Monczka (1999) argue that supply quality is the source for an imbalanced proportion of the inputs into their organisation's products, processes and services. The ability of suppliers to influence customer satisfaction also makes MSQ essential to longer-term market success (Chin et al., 2006).

Quality approaches to improve supplier or any company performance are embodied in a set of quality management practices, known as total quality management (TQM) (Lakhal et al., 2006). TQM is generally described as a collective, interlinked system of quality management practices that is associated with organizational performance. Kaynak (2003) suggested a positive association between TQM practices and organizational performance. The quality management goal of a company should be to meet company and customer needs through the effective use of capital and resources (Hajibrahim, 2007).

Talking about the quality concept and according to Hajibrahim (2007) the quality definition varies from different points of view. From the consumer's point of view it means "a product or service that is fit for use upon its arrival and throughout its expected life", from the supplier's point of view it is "a product or service that conforms to specifications", and from ISO's point of view it is "the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs." Quality is also defined as a moving target where all applicable elements of the organization must be dedicated to seek and understand the customer's needs, and to react to these needs and to changes in these needs.

Quality management principles are a comprehensive and fundamental set of rules or beliefs for leading and operating an organization aimed at continually improving performance over the long term by focusing on customers while addressing the needs of all stakeholders. A quality system is a management system that uses quality management principles and quality management standards (i.e., ISO 9001) to guide planning, operating, and improving all that must be done to lead and manage an organization (Ludwig-Becker, 1999). The QMS standards and guides can be used to accomplish strategic business objectives, to create a quality management system that fits the business, integrates company-wide operations, and makes profit. In the next part of this literature review is shown the aerospace quality standard regarding the manufacture scope of this thesis.

### **2. 2. 1. AS9100B certification**

Major manufacturers in the aircraft and aerospace industry identified quality suppliers as a valuable link in the SC. Instead of writing their own quality management system standard, the aerospace industry chose to build off the well-known ISO 9001:2000 quality management system standard (Gordon, 2006). AS9100 is based on the ISO 9001:1994 standards, it was published in 2003, and it was revised again as IAQG 9100 Rev. B to eliminate the withdrawn ISO 9001:1994 version (Gordon, 2007).

“AS” are America’s standards published by SAE (Society for Automotive Engineers) in 1999. AS9100 resulted from cooperation between major aerospace corporations, American Aerospace Quality Group (AAQG) and the Independent Association of Accredited Registrars (IAAR) (Gordon, 2006). AS9100 was made for aerospace manufacturers; it is basically ISO with 89 extra requirements. It has an emphasis placed on design control, process control, purchasing, inspection & testing, and control of non-conformances in the areas that have the greatest impact on safety, reliability and maintainability for aerospace products (Hajibrahim, 2007). AS9110 is the Quality System for aerospace repair stations and AS9120 is the Quality System for distributors (Gordon, 2007).

### ***Benefits and advantages***

According to Hajibrahim (2007), companies who have gotten and implemented the AS9100B as a QMS have experienced the following benefits: well defined and documented procedures

improve the consistency of output; their quality is constantly measured; corrective action is taken whenever defects occur; defect rates decrease; defects are caught earlier and are corrected at a lower cost; documented procedures are easier for new employees to follow; organizations retain or increase market share, increase sales or revenues. Its major benefits are on access to new markets and getting improved product reliability. Companies have better process control and flow, a better documentation of processes, reach greater employee quality awareness and reductions in product scrap, rework and rejections.

### ***Differences between AS9100 and ISO9001***

To become an aerospace supplier, as a basic requirement that companies need to comply, it is required to be AS9100B certified. As seen in the previous section, the AS9100B is based on the ISO requirements. In this section are shown those extra requirements found between ISO and AS quality systems (see Figure 2-4). This is useful for organizations that wish to become AS9100B certified and which have an ISO certification (previous step).

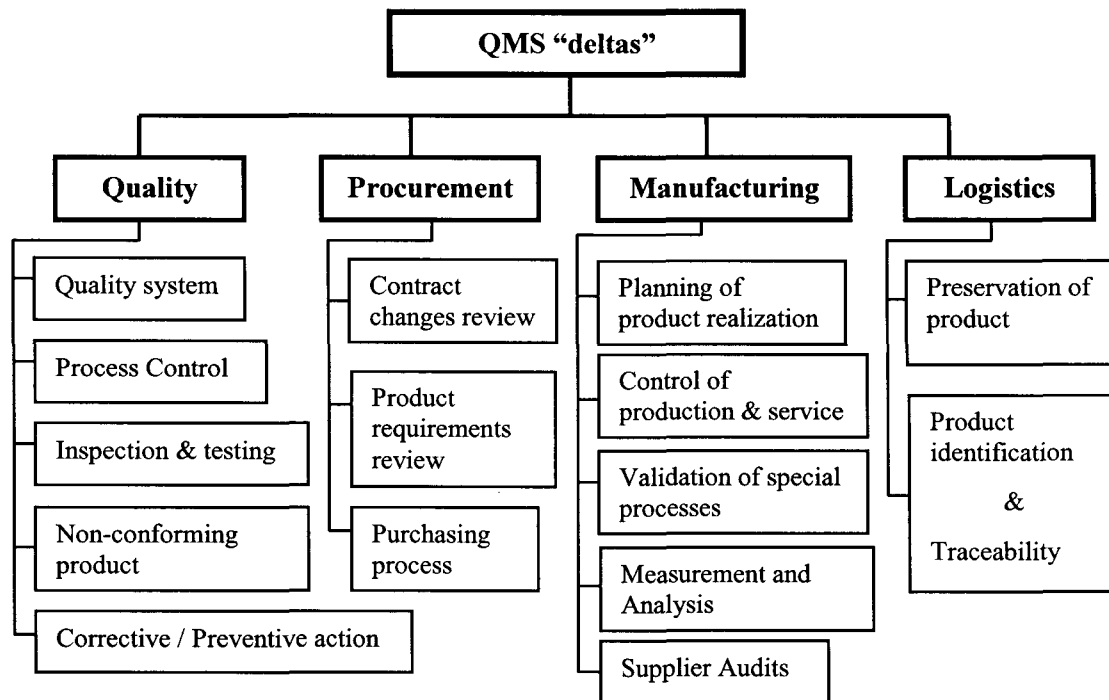


Figure 2-4. Structure of the differences between ISO and AS QMSs regarding manufacture.

Assuming that the requirements of ISO 9001:2000 are understood by the reader, i.e., the main requirements companies shall fulfill, then, for AS9100, the focus is limited to the differences (deltas) between ISO 9001:2000 and AS9100B regarding manufacturing (Sedlak, 2006). Design requirements are not included in this document since they are outside the reach of the standard. More detailed information about it is found in *appendix IV* of this document, where the clause and/or sub-clause number contain the differences (requirement), a summary that emphasizes the key points of each clause, and some comments or suggestions for the suppliers to be prepared before facing audits.

### **Quality**

*Quality system:* General (AS9100B-4.2.1f.), quality manual (AS9100B-4.2.2b.), control of documents (AS9100B-4.2.3.g.), control of records (AS9100B-4.2.4.), configuration management (AS9100B-4.3.)

*Process control:* Monitoring and measurement processes (AS9100B-8.2.3a-c.)

*Inspection and testing:* Monitoring and measurement of product (AS9100B-8.2.4.), inspection documentation (AS9100B-8.2.4.1a-d+.), first article inspection (FAI) (AS9100B-8.2.4.2.), design and/or development verification and validation testing (AS9100B-7.3.6.2.)

*Nonconforming product:* Control of nonconforming product (AS9100B-8.3.)

*Corrective / Preventive action:* Corrective action (AS9100B-8.5.2g & h.)

### **Procurement**

*Contract Review:* Control of design and development changes (AS9100B-7.3.7.). *Product requirements review* (AS9100B-7.2.2d.)

*Purchasing:* Purchasing process (AS9100B-7.4.1a-e.), purchasing information (AS9100B-7.4.2d-j.), and verification of purchased product (AS9100B-7.4.3.a-e.)

### **Manufacturing**

*Manufacture:* Planning of product realization (AS9100B-7.1.e.), control of production and service provision (AS9100B-7.5.1.), production documentation (AS9100B-7.5.1.1.), control of production process changes (AS9100B-7.5.1.2.), control of production equipment, tools and numerical control (NC) machine programs (AS9100B-7.5.1.3.), control of work transferred on

a temporary basis, outside the organization's facilities (AS9100B-7.5.1.4.), control of service operations (AS9100B-7.5.1.5.): To have a defined control of service operations.

*Special Processes:* Validation of processes for production and services provision (AS9100B-7.5.2a & c.)

*Measurement and Analysis:* Control of monitoring and measuring devices (AS9100B-7.6 & f.)

Supplier Audits: Internal audit (AS9100B-8.2.2.)

### **Logistics**

*Logistics (supply chain):* Preservation of product (AS9100B-7.5.5a-f.), product identification and traceability (AS9100B-7.5.3& a-d.)

If a company wants to be in the aerospace business it is going to have to follow the aerospace prime requirements. All customers speak with one voice: AS9100 is mandatory, for manufacturing in the aerospace industry (Sedlak, 2006). For special processes, a company must have Nadcap certification. The reason is to make sure there is a standardization of the norm, the way the business works. Everybody works thinks and controls their processes the same way, which removes the risks from the aerospace business. A supplier can work on any OEM/Tier 1 job. All will be done in the same way, and this removes variation and risk from the processes (Reid, 2007).

### **2.2.2. Nadcap certification**

Prime contractors, suppliers and government representatives work together in order to establish requirements for accreditation, approve suppliers and define operational program needs. This process results in a standardized approach to quality assurance and a reduction in redundant auditing throughout the aerospace industry. National Aerospace and Defense Contractors Accreditation Program (NADCAP) is administrated by the Performance Review Institute (PRI). Nadcap's mission is: "To provide international, unbiased, independent manufacturing process and product assessments and certification services for the purpose of continual improvement, adding value, reducing total cost, and facilitating relationships between primes and suppliers" (Nadcap webpage).

According to Reid (2007), an OEM can validate or accredit a supplier for special processes. Generally, material and process engineering are a team, who are responsible for creating OEM special control processes. They develop it in-house or for the supply base. Nadcap

does cover the surveillance after the initial OEM approval. Once done the company gets , the initial approval for that process, and every year or two, they revalidate it by doing audits. With Nadcap now, OEMs don't do annual audits of the processes. OEMs' supplier quality assurance teams sit with the Nadcap community. All together they create a check list. An OEM is part of the hiring screening of the auditors, responsible for overseeing the auditors who oversee Nadcap itself. OEMs' quality departments have teams for the whole Nadcap process; they do the surveillance. In the initial approval for the Nadcap process the OEM is responsible in quality, supporting engineering to do that qualification validating the suppliers (Reid, 2007). The Nadcap program has established an accreditation that includes the following commodities (13) (Nadcap webpage):

- Aerospace Quality Systems.
- Chemical Processing – based on the SAE standards AS7108, AS7108/1 and AS7108/2.
- Coatings – based on the SAE standard AS7109.
- Composites – based on the AC7118 checklist.
- Elastomer Seals – based on the AC7115 series of checklists.
- Electronics - based on the AC7119, AC7120 and AC7121 checklists.
- Fluids Distribution – based on the SAE standards AS7112, AS7112/1, AS7112/2 and AS7112/4.
- Heat Treating – based on the SAE standard AS7102.
- Materials Testing Laboratory – based on the SAE standards AS7101, AC7101/1-9, AC7101/11 and AC7006.
- Nondestructive Testing – based on the AC7114 series of checklists.
- Nonconventional Machining and Surface Enhancement – based on the SAE standards AS7116 and AS7117.
- Sealants – based on the SAE standards AS7200/1 and AS7202.
- Welding – based on the AC7110 series of checklists.

Each task group has its own audits to demonstrate compliance to SAE for each sub-process. This accreditation requires specialized audits against specific NADCAP requirements for individual processes, not the company's quality system. In fact, NADCAP process accreditation typically requires the company to be certified to AS9100 (or equivalent) before NADCAP auditing can be conducted.

### **2.3 Aerospace Supplier Qualification and Selection Processes**

In this section are presented the supplier selection and qualification processes nearest to the framework proposed in this document (chapter 3). The Supplier Selection Process of a Tier one to pick a supplier (Morissette, 2007), is seen as a standard process followed by this Tier one manufacturer, but supported with other processes and tools used by other OEM and Tier one companies (customers) explained in the subsequent sections, described in four *phases*: “1) *Clearly identify the requirements for program*, 2) *clearly communicate all requirements to candidate suppliers*, 3) *exhaustive supplier proposal review leading to team recommendation*, and 4) *award only when documents are negotiated to satisfaction*”.

*Phase 1: Identification of requirements.* In this first stage the customer clearly identify requirements for program by the next process. 1) The sourcing activity is launched (marketing); 2) the customer flow down is identified in order to know what people would be involved; 3) the program milestones are defined; 4) a sourcing plan is developed based on program milestones and product definition.

*Phase 2: Request for quotation (RFQ) process.* 1) The customer team validates RFQ documents; 2) candidate suppliers are identified according: engineering capabilities, engineering capacity, manufacturing capacity, operational performance, compatibility with strategy for product and offset/country requirements; 3) the RFQ package is built containing the performance specification for the product; 4) a forecasted program volume is made, 5) a schedule is designed (hardware requirements), 6) the customer defines a purchase agreement and the aftermarket services (if they apply), 7) the sourcing schedule and selection criteria are defined, 8) the qualified, required response is received from the supplier with its contact (technical and commercial), 9) and the commercial response format and technical response is received as well (form of compliance matrices).

*Phase 3: Proposal review: OEM/Tier1 recommendation.* Once received the proposal is reviewed. These technical and commercial proposals are reviewed by different team areas from the customer. The short term risk is established. Then, a negotiation is done and after it comes the final selection review and team recommendations, which produce a Market Feedback Analysis for that product(s). Then, a risk assessment is applied to the supplier (see



section 2.3.3), and finally some conclusions and recommendations are suggested before a contract is awarded.

*Phase 4: Award & MFA:* All documents must be negotiated to satisfaction. The award is only given when all documents satisfy the customer needs. Finally, the contract is signed and the MFA competition information is captured for further reference.

### **2.3.1. Supplier Identification Methods used by Customers**

This activity is done in the *phase 2* described above, when a customer (OEMs/Tier ones) is looking for a contractor, different sources and some instruments are used to place manufacturing jobs with subcontractors, once their scope of work is initially defined (*phase 1*, section 2.3).

Aerospace customers normally use questionnaires to request information about potential suppliers, which includes information principally about suppliers' manufacturing facilities and capabilities, material handling, manufacturing, design and capacity to meet production, quality systems and certifications, approval status with other customers, delivery, shipment processes, services, and ability to meet the customer contractual requirements (Friedman, 2007; Chambers et al., 2007).

Usually the OEM/Tier1 sends an evaluation questionnaire to a supplier, which is the tool by which suppliers can evaluate themselves against the criteria the OEM/Tier1s have set. According to Reid (2007) this instrument serves to know how many people work in quality, what kind of accreditations suppliers have, if the company is AS9100 certified, how are their processes, capabilities, capacities, what kind of work the suppliers do, for whom they work, and others.

### **2.3.2. Supplier Performance Evaluation**

After the customer reviews the request for information questionnaire (RFI) and validates the content of what the supplier is saying by multiple media, (customer looks for a manufacturing company), a potential supplier must have AS9100 certification or at least an ISO certification and be in the process of getting the AS certification (see figure 2-6). If SAE has approved and certificated the supplier, the supplier is recognized as having AS900 certification. The customer has confidence in the registrars, whom make audits at the supplier facility and its

QMS (Reid, 2007). Then, from a business point of view, the customer has the question: do I need to go and redo the audit? The purpose is to avoid expending a lot of cost in the beginning to audit all the new suppliers. In case of yes, with this new protocol, the customer has the ability to do it with the confidence of the registrar. A quality team now spends time overseeing the registrars, and headquarters make sure suppliers are following the process until they reach the accreditation. The customer's quality assurance department also follows the auditors into the suppliers facilities to make sure the auditors fulfill the needs that they are asking in the requests, and to have the right responses, because they are working on their behalf (Reid, 2007).

Big aerospace customers are now working on their SC. One of the first things, when a customer has a need (buying a product, a subassembly, or part), from one supplier to another or from itself to a supplier base, there is a decision where the customer puts together expert members from many teams (engineering, material processes, configuration, business people, etc.), where their perspectives are different and they have to be together to perform an evaluation (Reid, 2007). Customers have risk evaluation tools to look at whether or not a company is going to be capable, or if it is going to be a low or high risk (see section 2.3.3) (Chambers et al., 2007). If the supplier is already working for another aerospace OEM/Tier one, the risk could be minimum, but if is a brand new company (as in México), then the customer may need to have a larger development plan for these companies, that would be developed depending on the need. The initial risk assessment is: what is the need, depending on company a, b, c, what is their experience, do they have to be developed.

Aerospace OEMs and Tier ones are now working globally, and need to use these kind of tools to make their costs low. If there is not the scope of work for the supplier, a customer probably might not audit. If it is a larger scope of work, a major offload, the customer sees where the risk is, evaluates it; if it is high, the customer does not set up a relationship with the supplier (see Figure 2-6).

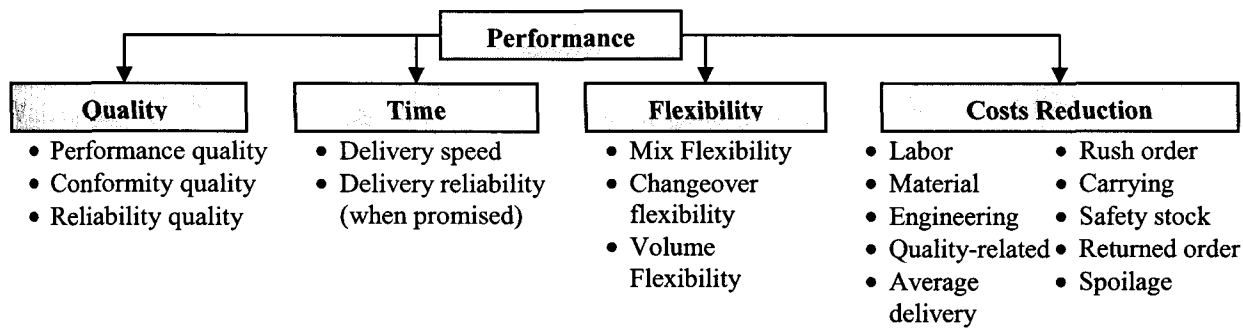


Figure 2-5. SC performance evaluation factors. Sabbaghi et al. (2007).

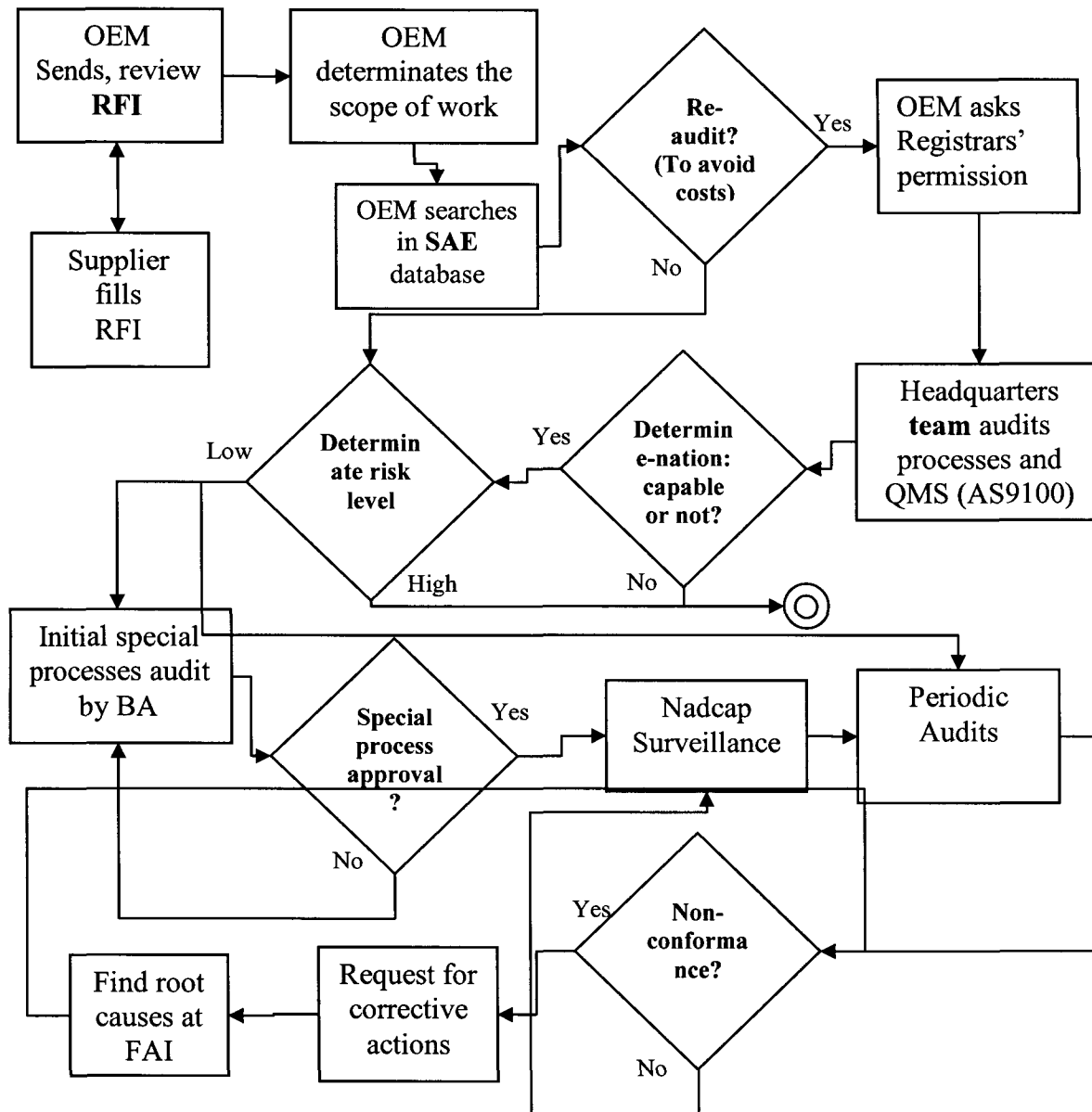


Figure 2-6. Standard supplier evaluation process followed by an OEM (adapted from Chambers et al 2007; Reid, 2007).

Supplier evaluation is considered as a prerequisite to further supplier development activities (Watts and Hahn, 1993; Hanh et al., 1990; Giunipero, 1990). Sabbaghi et al. (2007) state that quality, delivery, flexibility and cost are the main performance evaluation factors an SME must work for its customers' satisfaction (Figure 2-5). According to Bartlett et al. (2007) the aerospace division of Rolls-Royce Co. (RR) measures its supply base broadly under the indicators of quality, cost, delivery and responsiveness. In recent years this company has been focused on achieving price reductions, and is asking cost downs of its suppliers.

Cost models are also constructed and used in this process, considering things like the amount of material used, and the value added cost of a given supplier. Year over year cost reduction targets are normally built into the long-term agreements where suppliers are challenged to reduce the cost of a part while under contract by working jointly with the customer. The delivery measure is the percentage of orders fulfilled on time and in full. The required quantity and date is usually communicated using the customer's MRP (material requirement planning) system.



Figure 2-7. RR quality balanced scorecard. Bartlett et al. (2007).

RR has a quality balanced scorecard approach, and it has been operating it the last two

years (Bartlett et al., 2007). The quality balanced scoring system is the means by which the performance exhibited across a range of five quality performance metrics can be expressed as a simple percentage (see Figure 2-7). RR's business performance indicators for quality, cost and delivery are used as a way of highlighting the suppliers' areas that require improvement.

There are some other critical performance factors in a supplier evaluation process (Reid, 2007; Nicholson, 2007) such as to meet all the requirements and capabilities needed to get into the business, to work on a long-term status, to be accredited by SAE for having AS9100 as a QMS, and Nadcap accreditation for special processes (recognition applicable), and to have good management practices in all the organization levels with a desire and serious personnel conscious about safety as a principal aspect. Skilled people in manufacturing, engineering, quality are a key, and the company requires the business skills as well.

The SC selection criteria used by RR (Bartlett et al., 2007) is grouped in two categories: commercial and operational factors. The selection criteria related to the commercial factors are: how strong can be its relationship, if it's a strategic supplier, how is the supplier as an alternative compared with others, if the supplier has any interdependencies (joint initiatives seen in positive way), the level of business required to achieve the required return of investment (or to mitigate levels of cost avoidance), and the company size (larger companies are preferred because of the level of investment required). The operational factors are: the performances of the company, how high are its switching costs (any impediment to a customer's changing of suppliers), and its SC complexity.

### **2. 3. 3. Supplier Risk Measurement**

Quality performance is calculated by Goodrich Co. using a Quality Risk Evaluation as seen in the Figure 2-8 (Supplier Quality Risk, adapted from Chambers et al., 2007), shown below, where '1' represents low risk – GOOD and '10' represents high risk – BAD. The 'green' squares represent the minimum acceptable level for certified suppliers, which for Goodrich Landing Gear it's the equivalent maximum risk level: 30. SCAR (Supplier Corrective Action Request).

| Criteria                                                   | Importance | Risk Priority Level |      |     |     |     |     |     |     |     |    |      |
|------------------------------------------------------------|------------|---------------------|------|-----|-----|-----|-----|-----|-----|-----|----|------|
|                                                            |            | 1                   | 2    | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10 |      |
| Certifications (AS9100B/NADCAP)                            | 2          | YES                 |      |     |     |     |     |     |     |     |    | NO   |
| Number of customer escapes or disclosures (Past 12 Months) | 4          | 0                   |      |     |     | 1   |     |     |     | 2   |    | >2   |
| Parts Per Thousand rejection Rate (Past 12 Months)         | 1          | 0                   | 1.0  | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 |    | >5.0 |
| Total Number of Supplier Initiated Tags (Past 12 Months)   | 1          | 0                   | 2    | 4   | 6   | 8   | 10  | 15  | 20  | 25  |    | >25  |
| Number of SCARs (past 12 Months)                           | 2          | 0                   |      | 1   |     | 2   |     | 3   |     | 4   |    | >4   |
| On time Delivery (Past 12 Months)                          | 1          | 100                 | 97.5 | 95  | 90  | 85  | 80  | 75  | 70  | 65  |    | <60  |

Figure 2-8. Supplier Quality Risk. Chambers et al. (2007)

Performance is normally based on a rolling 12 month cycle. The "Risk Priority Level" is based on the supplier's 12 month performance.

Example risk calculation:

| Supplier                  | AS9100B Status | # Escapes or disclosures | PPT reject rate | Total Tags | # SCARs   | On time Delivery | RISK      |
|---------------------------|----------------|--------------------------|-----------------|------------|-----------|------------------|-----------|
| Past 12 Months            | Yes            | 1                        | 15              | 10         | 2         | 95               |           |
| Importance                | 2              | 4                        | 1               | 1          | 2         | 1                |           |
| Risk Priority Level (RPL) | 1              | 5                        | 10              | 6          | 5         | 3                |           |
| Importance x RPL          | <b>2</b>       | <b>20</b>                | <b>10</b>       | <b>6</b>   | <b>10</b> | <b>3</b>         | <b>51</b> |

After getting the evaluation result, bias for action are implemented for those suppliers with the highest risk. First, a formal notification is sent to these suppliers. Customer certified suppliers would be placed on a time period (e.g., 90 days) "probation" status. An evaluation of improvement is performed at the end of that period. The supplier permanently loses "certified" status if no improvement is evident. Approved suppliers (non-certified) are placed

on “hold” status and no receipt of additional business, either new purchase orders or increased quantities of existing orders would be given to them.

All suppliers need to develop an improvement plan which shall be approved by customer’s Supplier Quality Assurance (SQA) department and presented by the supplier to the customer within a period of notification. After this, there is a probation period after the plan is approved.

Continuous improvement (CI) effectiveness is also evaluated in order to eliminate waste and the cost of poor quality and improve on time delivery, according the concepts: Lean Manufacturing, Six Sigma, Total Quality Management / Total Productive Maintenance, Advanced Product Quality Planning (APQP) methodology (Chambers et al., 2007).

The plan consists of: 1) clear analysis of major issues that cause defects to go undetected, short term action, 2) short term and long term corrective and preventive actions, 3) steps that will be taken to achieve AS9100B registration. All suppliers would be subject to short term risk mitigation initiatives such as: a) 3rd party source inspection, b) customer Supplier Quality Source Inspection / onsite audits, c) receiving inspection at a customer or 3rd party inspection house, d) establish reporting metrics and inspection plans, or e) monetary penalties. Failure to comply would result in recommendation for re-sourcing of parts (Chambers et al., 2007).

The current SCM techniques used by customers in the supplier selection and qualification in order to close the gaps seen after the supplier evaluation process are considered important. This is why there is a need to explain SCM practices and their direct impact in the framework implementation.

#### **2. 3. 4. Supplier Development in Aerospace Industry**

Purchasers view their suppliers’ performance as lacking in the critical areas of quality and cost improvement, delivery performance, new technology adoption, and financial health (Morgan, 1993). As today’s firms focus on their core competencies, they become more dependent on their suppliers to meet ever-increasing competition. To compete in their respective markets, buying firms must ensure that their suppliers’ performance, capabilities and responsiveness equals, or surpasses that experienced by the buying firm’s competitors.

Thus, many buying firms actively facilitate supplier performance and capability improvements through supplier development SD.

According to Krause and Ellram (1997), SD can be defined as: “any effort of a buying firm with a supplier to increase its performance and/or capabilities and meet the buying firm’s short and/or long-term supply needs”. In practice, SCM activities vary significantly, ranging from limited buying firm efforts that might include informal supplier evaluation and a request for improved performance, to extensive efforts that might include training of the supplier’s personnel and investment in the supplier’s operations.

Firms may engage in SD as a reaction to competitive markets. Firms may also seek competitive advantage from strategic supply initiatives such as SD because of competitive pressures such as shortened product life cycles, fast-changing technologies, ever-increasing quality levels and cost-cutting by competitors (Hahn et al., 1990).

Krause and Ellram (1997) state that SD success factors are: the feedback of evaluation results to the supplier, the use of a supplier certification program, the site visits to the supplier, the visits to the buying firm by the supplier’s representatives, the supplier recognition, the training and education of the supplier’s personnel, and the investment in the supplier’s operation. Hahn et al. (1990) stated other factors such as the communication effort as timely, frequent, informal, having a greater number of contacts between the two firms and to have propensity to share proprietary information. However, the trade literature reports that buying firms believe suppliers are often weak in the areas of quality, reducing costs, delivery, incorporating new technology into products, financial health and handling design changes (Morgan, 1993). Buying firms may be able to raise suppliers’ performance significantly by expecting more from suppliers, communicating those expectations, and actively participating in the effort.

As noticed, various definitions exist for supplier development. These vary to suit the development objectives, the industry environment and the paradigms within which the initiatives take place. To date, there is only a small core of widely recognized data specifically referring to the subject of supplier development. A search of supplier development literature reveals a pluralistic scope:



1. Evaluating suppliers as a prerequisite to further supplier development activities (Handfield et al., 2000).
2. Providing feedback on supplier performance (Lascelles et al., 1989).
3. Selling the concept based on future benefits (Monczka et al., 1993).
4. Greater information exchange through common interface platforms (Monczka and Carter, 1988).
5. Performance and capability enhancements are possible by investing directly in the supplier in exchange for raised performance expectations (Monczka and Trent, 1991).
6. Cultural and technological interchange by implementing tour of duty training and secondments (Newman and Rhee, 1990).

The basis of these studies distills into seven principal elements:

- Identify and assess supplier's operations,
- Provide incentives and inducements to improve performance,
- Instigate competition among suppliers,
- Overcome resistance to change,
- Work directly with suppliers either through training or other activities,
- Assess and audit performance periodically,
- Develop information technology infrastructure and standard interfaces.

In the aerospace industry, qualifying a supplier could be as simple as closing the gaps, improving performance, etc. The real issue is that these companies which come from other industries want to take a different approach. In the aerospace industry, the supplier needs to get approvals to get into the business, and they have to put up the resources to fill those gaps (satisfy audits, etc.). To qualify a supplier could mean spending money, but a Tier1/OEM needs to be sure that this is the right company to work with. If it is, then the process begin, and the supplier must work to be qualified. An aerospace customer (OEM/Tier1) requires the supplier plant to get there before the contract, and to keep going with a continue improvement philosophy because airplanes have a very long life.

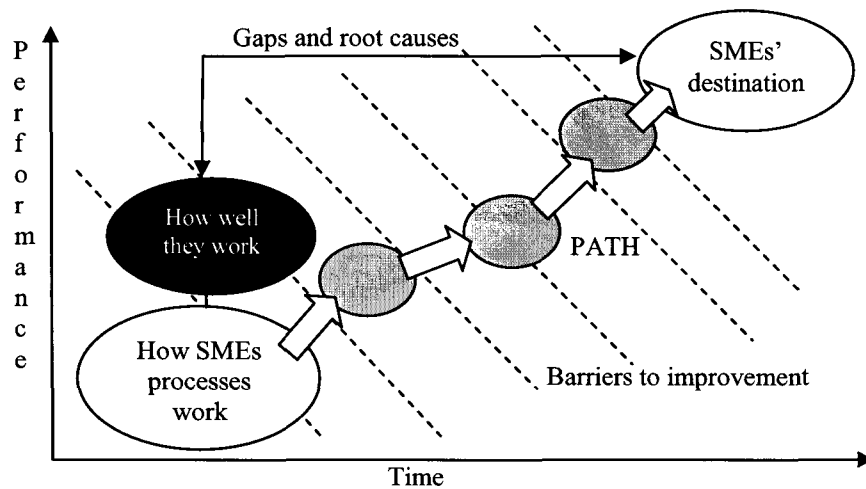


Figure 2-9. Model for supply chain change. Ayers (2006).

In aerospace the key challenge and the biggest barrier to a supplier is how to make money. There are some entry barriers that companies need to qualify: high precision, technology, quality, financing, certifications, lead times, raw materials, special processing (see Figure 2-9). Moving from the automotive industry to the aerospace industry, which is the case of many Mexican SMEs, means to move from a high volume to a low volume and from low complexity to a higher complexity of parts and products (see Figure 1-1). There are similarities between the business management processes of the aerospace and other industries, such as automotive, although clear differences exist in certain specific quality requirements (see appendix IV) where documentation and traceability policies are the biggest. To get this conversion, a company needs to invest in new technology, new systems and in human resources (Amado, 2007). The framework presented in chapter 3 tries to serve as a path, letting the SMEs know what the supplier qualification process is in the aerospace industry according to OEMs, Tier1s and actual suppliers.

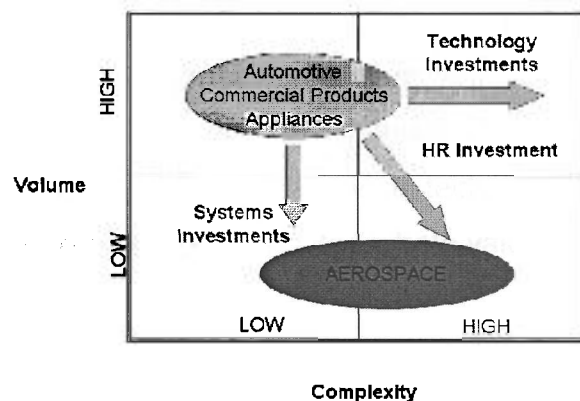


Figure 2-10. SMEs in industry transition. Adapted from Amado (2007).

According to Krause and Handfield (1999) SD is simply a process to select appropriate new suppliers to meet a firm's requirements and that which involves active intervention to upgrade existing suppliers' capabilities. In order to develop appropriate technology capabilities, suppliers need to engage in a process of anticipating the technological future which is termed "technology lookahead." Technology lookahead relies on an integrated understanding of market needs and opportunities and of the potential from new advances in technology, including disruptive technologies that may come from unexpected sources. SD has little direct impact on supplier technological capability, but it does have an important indirect effect through facilitating the processes of technology innovation and technology lookahead. The innovation advantages associated with SMEs are responsiveness, lack of bureaucracy in decision-making, and ease of internal communication, but these assets do not help with long-term planning and developing new technologies.

Involving suppliers in NPD is an extension of concurrent engineering (CE), which has become popular as a means to cut product development times, to improve quality and design-for-manufacture and to cope with the increasing complexity of products. The involvement of suppliers in NPD is very likely to relate to technological capability in some way and may lead to the informal exchange of long-term technology lookahead information (Reed and Walsh, 2002).

Large companies have the opportunity to enhance the technological capability of their suppliers. This may be achieved through SD, by sharing best practices in specific technologies, or by sharing technology strategy. For this to be effective, large companies

need to ensure that senior engineers and technologists are genuinely engaged with the SD process. It may, however, be more important to ensure that channels of communication are maintained between the right people within (and perhaps beyond) the supply network. This requires recognition of the processes which enhance technological capability and of their significance in increasing the competitiveness of the whole value chain.

### **2.3.5. Approval of Suppliers**

After the OEM or Tier one does an initial assessment of a potential supplier about its capabilities, as commented before, the process goes as follows (Chambers et al., 2007). a) There is a request for Supplier Quality Assurance (SQA) to approve the supplier. b) The SQA department evaluates the supplier and determines its ability to meet quality system and specific quality assurance requirements. An assessment is mainly based on:

1. Documented accredited registration to SAE AS9100B or ISO 9001 standards.
2. Results of a Customer supplier quality system questionnaire.
3. Review of recent approval status and/or quality history with other major aerospace contractors (if it is already a supplier in the aerospace industry).
4. Review of product, service type, complexity, and effect on final product quality.
5. Review of the supplier's quality system manual and/or procedures.
6. Results of a survey (normally on-site) by the customer.
7. Results of NADCAP audit (if special process required).

c) The supplier gets certified by customer SQA and formal documentation is provided. d) A Designated Supplier Quality Assurance Representative (DSQAR) is assigned.

The aerospace supplier maturity grade perception depends on its manufacturing process technology, on its knowledge level of business management, on its manufacturing processes and on its technical expertise. There is a disconnection between the customer expectations in terms of maturity in the supplier candidate to be developed and its actual performance. It is because many suppliers have a good performance in their manufacturing processes, good expertise, but they don't have the correct aerospace industry terminology and evaluation methods, e.g., language is an issue in some cases (Karapetrovic and Willborn, 1997). The supplier competitiveness and maturity is habitually subjective. A method to define more

certainly the preparation level of a company to be considered or not as a candidate to become part of the aerospace industry SC needs to be established.

## **2.4 Discussion**

In this chapter we understood the aerospace SC characteristics, its structure, quality management systems in a manufacturing approach. Supplier qualification requirements, tools, concepts and evaluation techniques were analyzed. Supplier qualification concepts identified here will be later used to outline a framework to define a path for SMEs that will expedite their process with the aim of becoming qualified aerospace suppliers. From the previous evaluation, important issues are:

- Supplier identification methods used by customers were evaluated to determinate the supplier capabilities using standard approaches described in section 2.3.1. These assessments are often applied to actual aerospace suppliers in North America as a first step in the evaluation process. The issue is that it does not provide deep information about the SMEs, so an aerospace customer could think an SME is ready to begin a quotation process and most of the time, in LCCs such as Mexico, these suppliers frequently fail in some phase of the procurement activities.

Opportunity area: To create standardized tools by means of which SMEs can be assessed about their understanding level of aerospace requirements. It can also serve to identify where they are placed and what do they really need to do with the aim of becoming attractive suppliers for aerospace customers.

- Supplier performance evaluation techniques and tools were found and analyzed (section 2.3.2). These are really accurate given the nature of the industry about the needed security and quality effectiveness. The information shown in this section is not often known by the potential suppliers, they need to establish some readiness before facing customer audits and evaluations. However, researchers have developed studies about these performance indicators for specific aerospace customers.

Opportunity area: These tools are not satisfactory to assess the current suppliers' performance in LCCs. Supplier evaluation techniques and tools are needed before

suppliers become qualified in LCCs to let them know the areas that require improvement inside their processes and facilities. There is not a common criteria defined as a research public document for the aerospace industry, especially for future aerospace suppliers.

- A supplier risk measurement tool was reviewed and key elements identified; so, it will further serve to enhance the self-assessment tool in order to discover gaps which need to be closed.

Opportunity area: SMEs could then focus on their weaknesses and improve their processes by getting ready for these measurements.

- SD best practices in the Aerospace Industry were found. It was seen that each customer has different approaches to this subject, and even Tier one companies take a more serious commitment developing sub-tier suppliers and managing almost the whole SC going down vertically. Common SCM practices for any customer at the top of the chain need to be defined; so, an SME can become qualified by any customer. The approval of suppliers is the last stage where the SMEs can get the award, which means signing a long-term contract, which has not been often seen in a Mexico with SMEs yet.

Opportunity area: The tools presented in the literature review are not adequate to assess the future aerospace suppliers in low cost regions, today there is a lot of responsibility of the supplier in the qualification process. These tools to assess supplier performance are not considered for suppliers in LCCs yet. It is needed SD before companies become suppliers, it will also benefit the SMEs' financial side.

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## CHAPTER 3

### 3. FRAMEWORK

In this chapter a framework is proposed and its concerned activities are explained in detail to define the supplier qualification process that Mexican metalworking SMEs need to follow in order to expedite their development to achieve customers' qualifications and certifications. This framework was created to facilitate the creation of manufacturing metalworking aerospace suppliers, but it could also be applied to other industries.

This chapter is divided in two sections where the two main contributions of this thesis proposal are presented: the Framework (Figure 3-1) and the Self-Assessment Tool (section 3.2), both for future aerospace suppliers in LCCs. In the first section a framework and its elements are described in order to present the basis for designing the methodology. In second section a self-assessment tool is defined and how it can be implemented as a case study representing the first two stages of the framework. The purpose is to diagnose the key management areas on which SMEs need to work.

The qualification of suppliers to the aerospace industry has not been proposed before as a product of methodology. The reason could be (as remarked before, section 2.1.1) that for decades OEMs were doing almost all their operations inside their facilities, and then they began contracting companies in their countries doing only core processes in-house (Reid, 2007). In the aerospace industry, outsourcing to Mexico has just begun a few years ago, and there is no other framework in the literature that describes the process to become a qualified aerospace supplier. The nearest descriptions are what Morissette (2007), Reid (2007) and Chambers et al. (2007) illustrate from an OEM/Tier 1 company perspective, but it represents the internal process to pick a an actual aerospace supplier and begin a contract (section 2.3).

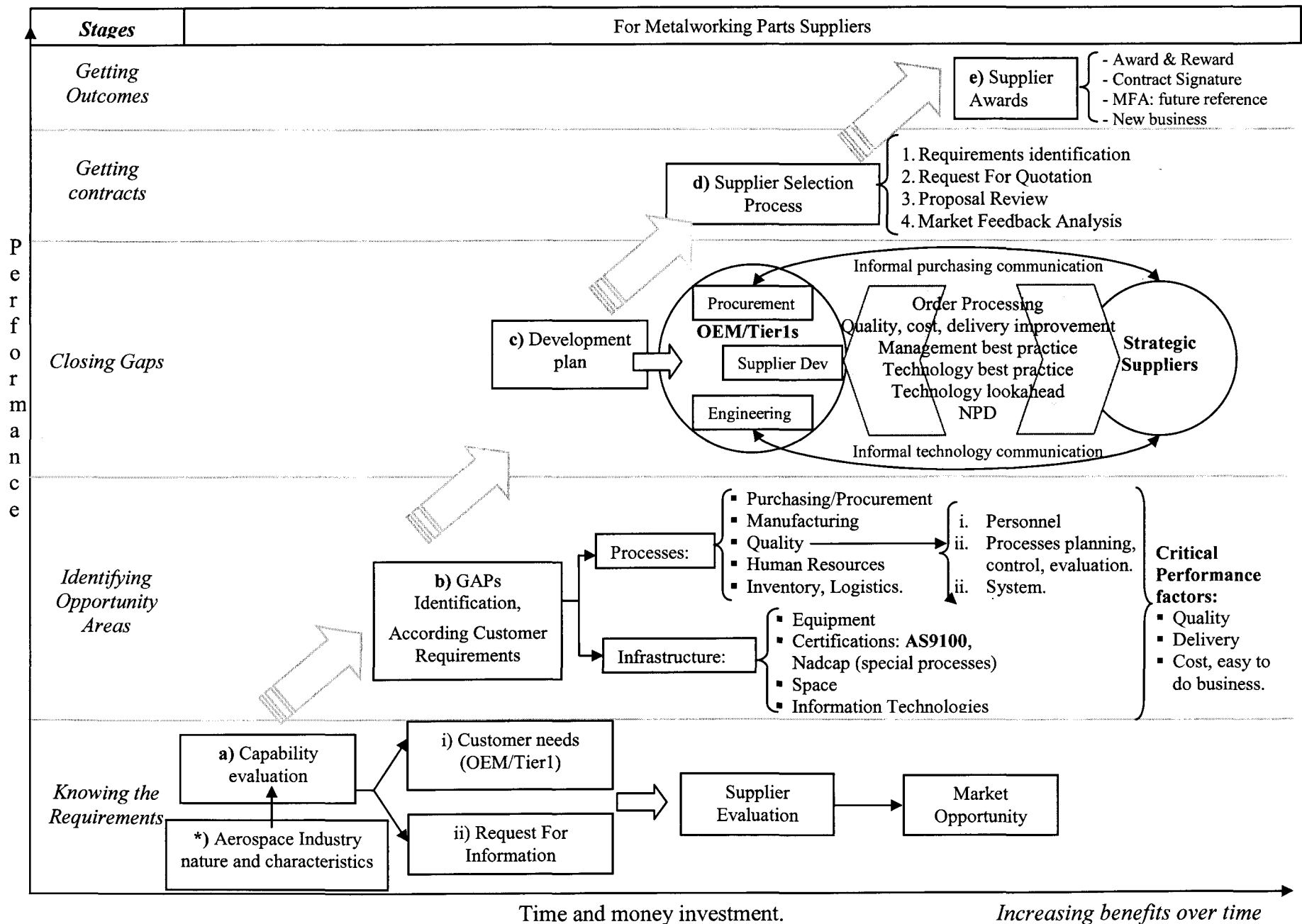
The components of this framework where obtained from a research about the best aerospace industry practices in North America where actual suppliers are developed with the aim of increasing their performance in the areas here represented. This framework is to qualify future suppliers, to help them to become qualified before knowing anything; it will help them to take decisions. This thesis aims SD for supplier qualification, by the application of

this framework. It hasn't been addressed before, especially in LCCs; this is a first attempt to, by using SD techniques used before but after companies become suppliers.

See Figure 3-1, on the next page.



**Figure 3-1. Framework for the Qualification of Mexican SMEs as Suppliers in the Aerospace Supply Chain.**



### **3.1 Framework for the Supplier Qualification Process in the Aerospace Industry.**

A framework for a supplier qualification process is proposed to support the supplier qualification methodology. The framework provides a guideline to support and to structure the different stages of the methodology. This framework is mainly based on the aerospace supplier selection process practiced by OEMs and Tier ones companies and the common quality, manufacturing and procurement requirements. The methodology, as a consequence, is supported by main elements of the framework in order to provide a set of activities to expedite aerospace customer certification status achievement.

This thesis work states that there are three main aspects in aerospace supplier development where companies need to improve: financial, technological and managerial (See Figure 3-2). As stated before, the scope of this study is mainly focused on the managerial side. Companies are requested to have excellent quality, management, engineering skills and practices, i.e., 1) AS9100 quality system certification is a must in aerospace industry (Reid, 2007), which has an emphasis on design control, process control, traceability, purchasing, inspection, testing (sub-supplier control), and control of non-conformances (Hajibrahim, 2007); 2) financial is an important issue as well because suppliers need long time health and high value assets are involved as technology capabilities, (manufacturing equipment and information systems) (Friedman, 2007), etc.; and 3) technical expertise also plays an important role to fulfill the product specifications and requirements which are also taken in consideration, for instance, to have the technical expertise to interpret the drawings and quickly set production up is essential.

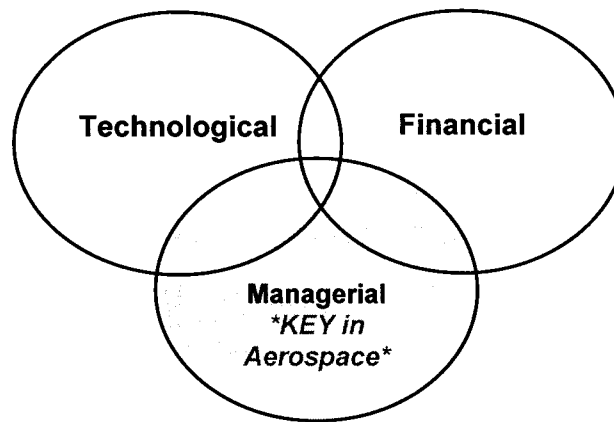


Figure 3-2. Main aspects in the SCD towards aerospace industry: Financial, Managerial, and Technological.

The framework is subdivided into five main stages (Figure 3-3): i) knowing the requirements, ii) identifying opportunity areas, iii) closing gaps, iv) getting contracts and v) getting outcomes. These stages reflect the primary activities occurring in each part of the supplier qualification process in the aerospace industry. Each stage is subdivided into activities that should be performed in order to consolidate the supplier qualification process (Figure 3-1).

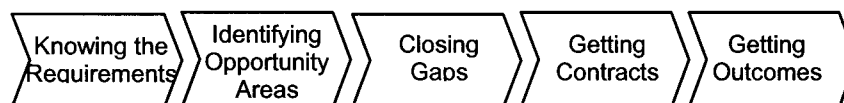


Figure 3-3. Main stages of the supplier qualification process in aerospace industry.

### 3. 1. 1. Knowing the Requirements

A company which wants to become an aerospace supplier must understand: 1) the industry nature, structure, characteristics, and context (see sections 1.1, 1.5, 2.1.1, 2.1.2, and 2.1.3 in this thesis); 2) the differences between this industry and the industries in which it has worked before, knowing the QMSs differences is a good approach in the management side of the company (see sections 2.1 and appendix IV); 3) also it is very important for candidate companies to understand the state of the art in evaluation instruments that aerospace customers use to measure supplier capabilities in different organization areas they look at, in order to know how to fulfill the requirements before making quotations (see section 2.3 and its sub-sections).

This is a way for suppliers to find market opportunities by which they can sell operations,

parts, products, sub-assemblies and components to customers. As stated in chapter 2.3.1, aerospace customers use different sources to pick a supplier, such as: request for information questionnaires, current suppliers, sales representatives, information databases, experience in their purchasing personnel, trade journals, trade directories, global suppliers (U.S. department of commerce), industrial trade shows, second party or indirect information, internal sources, internet searches, etc., to name a few. The problem is that these instruments used by customers are useful only to assess the supplier capabilities, but not to instruct them and let them understand the industry nature, characteristics, requirements, etc. It is believed that one half is the supplier customers' search and the other is the customer suppliers' search. Today OEMs/Tier ones want to reassign many jobs from North American and European suppliers to LCC suppliers (Mexican suppliers) (Friedman, 2007).

This framework stage serves only as an instrument to let the SMEs understand the requirements. The next step is to receive a brief self-assessment from the customer and to begin a process applying it to the SME to obtain the information about the gaps. It would be about implications in machinery investments, IT, people training, certifications (AS9100 and Nadcap if special process), management skills, etc. Once the supplier capabilities are identified and the gaps solved, the customer can begin a procurement process in order to assign a job for the supplier. In the next sections more details of this framework are described.

### **3. 1. 2. Identifying Opportunity Areas**

Standard supplier and product quality requirements for the aerospace industry were found during this research project. During this study it was seen that some SMEs in México often have the machines, equipment, infrastructure (investment), but some of them are missing engineering and management skills. So they need to restructure the company in order to fulfill these requirements. The investment capacity and infrastructure play one half of the role and the other half is played by the engineering and business skills of the company. These last capabilities represent opportunity areas which suppliers need to identify before beginning any development process in order to make an effective plan that will benefit them in further stages of the proposed framework. In this section there is a summary of the management main process requirements which suppliers must measure inside their companies to auto-

evaluate themselves, according to the scope of this document: procurement, manufacturing, quality, logistics and infrastructure. From this section, a self-assessment tool was derived; it is shown in section 3.2. (For terminology definitions see appendix I).

### **a. Procurement**

#### *Contract Review*

- During a contract review process, an SME must review feasibility and that all technical information has been received and understood by their departments.
- Material substitutions (MS) are not allowed unless authorized by engineering drawing / model, material specification, customer MRB (Material Review Board) disposition or superseding of a material specification. In those cases, suppliers may request a material substitution by completing an Engineering Change Proposal Request (ECPR).
- SMEs must have an Advanced Product Quality Planning (APQP)/Control Plan. In this control plan, as a supplier shall establish a pre-planning method for all new critical parts, maintaining appropriate documentation of:
  - All identified Key Characteristics.
  - The manufacturing process elements that influence variation in the Key Characteristics
  - Control techniques and measurement methods

#### *Manufacturing Plans*

- Processors need a customer (Tier 1/OEM) review and approval.
- Manufacturing plans shall be validated to the design specifications to ensure full compliance and accuracy in accordance with AS9100B by the purchase order holder.
- Manufacturing planning (MPS) is required to be on record for all individual components.
- The supplier could need to develop and implement a Quality improvement initiative to ensure its yield target is achieved and maintained.
- Manufacturing of parts commence only after the plan is approved.

*Failure Mode Effect Analysis (FMEA) method (see definitions in appendix 1)*

- 
- The supplier shall implement a method to identify potential failure modes for each key critical parts and key process characteristic.

#### *Offload/transfer of work*

- When using a sub-tier for rough machining and/or special processing, suppliers shall ensure the capability of all offload sub-tiers and the quality of all product.

#### *Flowdown*

- Suppliers are responsible to review requirements, determine contractual impact, notify applicable buyer of the impact (if any), and take necessary actions to ensure compliance to requirements.
- Supplier shall have a defined process to review and incorporate drawing revisions/changes.

#### *Purchasing process*

- Partnerships and ongoing relationships between OEM/Tier1s and suppliers.
- Bimonthly and/or annual production forecasts are often given to the suppliers.
- Purchase orders might be published by an electronic system: e-mail, web page (suppliers can monitor, do the boarding, know requirements and start production).
- Drawings and specifications are often transferred to the supplier on "build to print" documents.
- Outsourcing is practiced very often.
- To know how to buy internationally is basic, because a company in aerospace is not competitive on its own.

#### *Raw materials*

- Suppliers shall have a method to test each batch / heat / lot of material and conduct annual raw material verifications.
- Approval of raw material suppliers / forgers / casters based on:
  - ISO9002 certification and QMS audit results
  - Initial survey
  - Laboratory control for test samples
  - On-site audits of supplier (if required)
- Annual verification shall be performed by suppliers and results provided to the customer.
- Suppliers shall submit a sample of each material type noted below to a certified laboratory.

### *Foreign Material Requirements*

- Special requirements apply to material produced in company(s) located in a country which does not have a Bilateral Airworthiness Agreement (BAA).
- A product verification plan shall be submitted to customer(s).

### *Nonconforming material*

- When performing inspection, all forging suppliers shall reject and remove all detectable indications (e.g., laps, cracks, seams, bursts, ferrite fingers, inclusions, porosity, laminations, etc.) and re-inspect by applicable method to ensure their removal.
- For standard components it is necessary to maintain traceability to actual manufacturer and manufacturing lot; to ensure that all standard hardware with OEM design authority is procured from approved sub-suppliers; and to ensure that First Article Inspection records for all standard hardware.

### *Purchased product requirements:*

- To purchase materials and to contract special processes from approved suppliers by the customer could be mandatory.
- FAI (First Article Inspection, see appendix 1) verifies the final product for the process in detail, audits for special processes, and laboratory tests.

## **b. Manufacturing**

For structural parts, principally aluminium and stainless steel, the process capability is given specifically by the part, depends on it. Each customer has a classified table according to the parts types; this is an internal classification that includes the machine with its tolerances, processes, etc., and descriptions given depend on each specific part and its processes.

### *Manufacture*

- Parts are often manufactured with high value added, many processes, complex manufacture, (welding, rolling, points, guides, etc.). This occupies a lot of installed capacity.
- An SME strategy must be oriented to: high precision, high quality, delivery on time, low volume, continues improvement.

### *Special Processes, brief description of general requirements*

- NADCAP certification is required or special processes (see section 2.2.2).
- Existing customer approval (OEM).
- Customers audit processor's quality system and process controls. Exceptions are based on customer Quality Management reviews.

### *Use of Approved Processors*

- Only customer approved sources shall be used to perform special processes on aircraft production parts manufactured for the customer (OEM/Tier one).
- Suppliers are responsible for ensuring that approved sources meet the requirements of the applicable specifications defined on engineering drawings / models.

### *Non-destructive Testing Procedure and Technique Approval*

- Non-destructive testing (NDT) procedures and techniques shall be approved by a certified (certain level) of the applicable NDT process.
  - An approval signature is required on applicable procedures and techniques.
  - Certification shall be from a recognized, independent approving body.

### *Properties of Parts*

- Suppliers shall be granted authorization by the customer Material Review Board and/or Materials & Process Technology before performing a special process.
- Special process (e.g., heat treating) source shall maintain all necessary documentation and data for each part for any future traceability.

### *Measurement and Analysis: Statistical Control Methods*

- Suppliers shall implement measurement device control.
- Suppliers shall implement statistical process control for all critical manufacturing, processing, and identified key characteristics.
  - All manufacturing machines shall be evaluated for statistical process capability (Cpk) based on FMEA analysis of characteristics.
  - Suppliers should feel free to use low cost methods of statistical analysis (e.g., "QI Macros for Excel").



- Suppliers shall identify and analyze internal and external performance indicators using such tools as: Pareto analysis, cause-Effect/Fishbone/Ishikawa diagrams, the “5 Why” process, the “8D” process, etc.

#### *Control Plan Availability*

- Control plans for identified key characteristics shall be made available upon a customer request.

#### *Audits*

- In customer audits of suppliers, the customer will establish an audit schedule of suppliers and processors based on risk analysis.
- All suppliers and processors shall maintain an internal audit system.
- Suppliers shall demonstrate control of all sub-tiers.

#### *Human Resources (HR)*

- For special processes, the process and the worker must be certified; customers validate technical employees' capabilities.
- Managers connected at all levels.

### **c. Quality**

#### *Suppliers' Quality system*

- Certified suppliers must have a plan in place for 3rd party (registrar) certification to AS9100B.
- Approved suppliers: to maintain QMSs that meet as a minimum the applicable requirements of SAE “AS9100B”.
- Surveillance of suppliers registered to “AS9100B”: periodic process audits, and/or supplier performance evaluation.

#### *Processors*

- Complete certification of special processes to NADCAP.
- Approved processors' quality systems shall be compliant to AS9100B.
- Quality records are to be maintained for no less than a specified period of years.

#### *Right of access to facilities, personnel and records*

- For the customer(s) and other authorities, for quality and management systems reviews or product / process validation evaluations or investigations.
- Ensure compliance to ITAR and E.A.R. requirements when handling Customer parts and documentation.

#### *Process control*

- Supplier's document for recording manufacturing and inspection of product.

#### *Inspection and testing*

- Quality verification for all product purchased by a customer
- To detail the material and special processes used for all details and sub-detail components of the ready made part / assembly.
- Documentation shall be in English.
- First Article Inspection (FAI) shall be performed on the first piece of a new or delta production run.

#### *Material Certification requirements*

- Laboratory certifications
- Approval/disapproval of material
- OEM consigned material shall be accompanied by a Certificate of Conformance.

#### *Sub-Supplier control:*

- By ISO and AS certifications, customers have an authorized supplier control, and they evaluate internally delivery times and quality.

#### *Nonconforming product*

- Suppliers shall not perform unauthorized rework to nonconforming product
- Suppliers shall not ship nonconforming material without receipt and completion of the customer MRB disposition unless authorized by MRB or the customer quality department.
- Suppliers shall have a process for identification of nonconforming product.

#### *Supplier Paid MRB Administrative Costs*

- Suppliers are responsible for administrative costs incurred by the customer of supplier manufactured nonconforming product.

#### *Customer Returns*

- All items returned to the supplier by customer shall be documented.

#### *SC control Vs non-conformance*

- Suppliers must have a quality clinic (laboratory) to eliminate potential failures in the process and a process for corrective failures in a space inside the plant.
- Apply corrective actions to any defect, failure or non-conformance product.
- To inspect each end process.
- First part fully inspected by the DSQR (Delegated Supplier Quality Representative) from the customer side and a report must be generated.
- Customers perform periodic audits to suppliers (commonly once a year).

#### *Corrective / Preventive action*

- When a disclosure occurs, the supplier shall provide a root cause and corrective action plan within a period of time of the disclosure.

#### *Response Content and Time Requirements*

- The supplier shall contain and identify all suspect products including inventory, work in process and shipped product.
- Root Cause and Corrective Action Plans shall be received within the time noted on the request.
- Supplier shall have corrective action responsiveness in case of non-conformance.
- Supplier shall have a Failure Analysis Reporting (FAR) system for repaired units.

#### *Continuous Improvement Requirements*

- Suppliers shall implement an internal Continuous Improvement Program which may consist of: Lean Manufacturing, Six Sigma, Total Quality Management / Total Productive Maintenance or APQP (Advanced Product Quality Planning) methodology.

#### *CI Goal*

- The goal of the program shall be to eliminate waste and the cost of poor quality and improve on time delivery.

#### *CI Facilitation*

- The customer could supply SQA CI specialists to facilitate improvement events.

#### **d. Logistics**

- No inventory orders are usually triggered, orders based on purchase orders and/or the forecast.
- The SEM must be able to work with low inventory levels, on a Make To Order (MTO) basis.
- High mix of customers, from aerospace industry and other industries: low volume, high mix of products.

##### *Product identification: Part-marking and Serialization*

- Part-marking and serialization shall be identified in the supplier's control plan/manufacturing documentation for all new parts.
- All products shall be identified with the customer's part number as required by the engineering drawing and specification requirements.

##### *Service and warranty*

- The company must have a control of material.

##### *Repairs*

- All repair and rework requires documented evidence of work performed.

#### **e. Infrastructure**

##### *Certifications*

- AS9100B must be the general Quality Management System (QMS), and Nadcap certification is needed for each special process. The three major factors evaluated are all equally important: quality, cost and delivery.
- The SME must be able to receive independent authorities, in an annual basis, that do audits about the certifications. Also customers measure the supplier performance and QMS mainly about:
  - Equipment Maintenance
  - To have a good metrology system in place
  - Secure people contracts
  - Flow down: requirements transferred onto their shop floor

- Personnel training
- Supply chain management, corrective action management system
- Process control, measuring system
- To capture any defect before the product comes to the customer, on time

### *Tooling*

- The tooling capabilities are really important to be audited, constantly measured and all procedures documented.
- Parts must be reviewed and audited in the FAI (First Article Inspection). When a non-conformance occurs, the tooling requirements are audited.
- In manufacturing, part of the first article inspection is to make sure that the tooling is being inspected. There is a first article in the tooling, first process, that has been in place there, internal inspections if necessary depending in the product line.

### *Information Technologies*

- For Mexican SMEs, which are in the early stage beginning the conversion, it is good to have IT capabilities, but it is not a requirement for an SME supplier, i.e., enterprise resource planning, ERP (Kennerly and Neely, 2001), and material resource planning, MRP, which Tier 1-2 companies commonly have. Raw material planning and production planning is the kind of IT tool that a structural parts aerospace supplier should have. The CAD files are given to suppliers in CAD software extensions (CATPart, IGES, etc.), and it is fully recommended to have the correct software capabilities which could read drawings and other files.

The most critical performance factors in a supplier evaluation process, as seen in chapter 2, definitely are quality, delivery and cost. After the OEM/Tier one (customer) looks at the scope of work that would be given to a supplier, probably engineering and quality teams are sent to supplier capabilities to do evaluations. A sourcing team goes in the beginning, to quickly perform an evaluation, and then quality people go for a more serious evaluation. If the customer is going to work with that company, another multidiscipline team is sent to do a deeper risk evaluation, to make sure this company is getting AS9100 certified, and to help their processes to be more robust. Keeping in mind the previous criteria and parts of the next

stages of this framework, the self-assessment tool described in section 3.2 of this document was created.

In summary, an OEM/tier one audits a supplier in terms of its QMS:

- Make sure the supplier maintains its machines,
- Make sure the supplier has contract review people,
- Design, how do they transfer our requirements onto their shop floor,
- Training programs for their personnel,
- Supply chain management, corrective action management system,
- What kind of process control do they have in place?, how they are measuring the right things?
- To see if they capture any defect before the product comes to the OEM/tier one before the delivery date or actually escaping.
- About metrology, to make sure the supplier has gotten a good metrology system in place. Ten critical elements of a metrology system are considered for efficient and effective implementation (Westcott 2005): personnel; quality plan; control of documentation; control of inspection, measuring and test instruments; nonconforming products and services; corrective action; control of purchases; customer supplied products.

Aerospace customers look at their entire operation, and do gap analysis. Depending on that they could go or not go forward contracting a supplier. Even if the customer thinks that it is financially beneficial to go forward, it may have to put teams of people in there, to work with the supplier to make sure they will be giving the best contract for the customer.

### **3. 1. 3. Closing Gaps**

A supplier development plan is needed once the SME has found its opportunity areas. This section of the thesis aims to increase the effectiveness of a supplier development program for future suppliers in order to enhance their performance in the critical areas of quality, cost improvement, delivery performance. These best practices have been used to develop actual suppliers in North America and it's expected to be also effective developing future suppliers in LCCs. New technology adoption and financial health, stated by Morgan (1993), are out of the reach of this study, and are only partially considered.

In the previous stages, customers have identified suppliers for development and communication has been initiated between customer and supplier's executive management. After knowing the requirements and having communication with a customer, SMEs can now follow a customer's certification programs. OEMs/Tiers ones studied have their own supplier certification program. It is important to follow actual and specific customer evaluation techniques especially for the kind of jobs supplier will do and the type of parts being produced, i.e., aircraft part quality requirements depend on the level of "flight safety" or how "critical" the part are (Chambers et al., 2007).

According to the SD success factors seen in section 2.3.3 (Hahn et al., 1990; Krause and Ellram, 1997; Reed and Walsh, 2002; Handfield, 2006; Amado, 2007) and the previous stages of this framework supported by chapter 2, a methodology is presented here that SMEs can follow in collaboration with aerospace OEMs/Tier ones to close gaps previously identified.

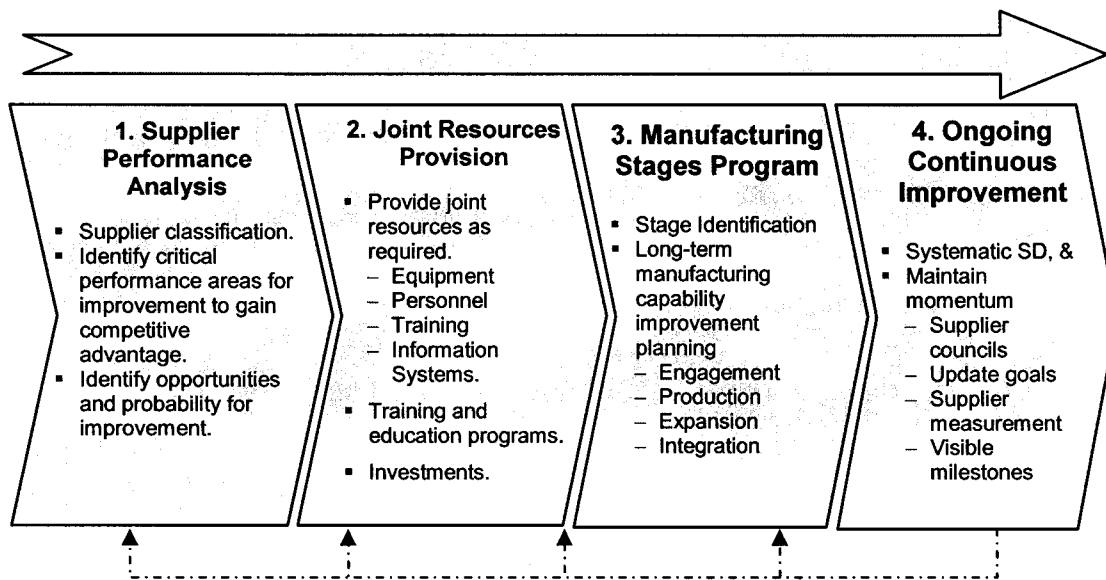


Figure 3-4. Strategic Supplier Development Process Planning for future aerospace suppliers.

### 3. 1. 3. 1. Supplier Performance Analysis

Analyze supplier evaluation results and customer's feedback. The OEM/Tier one can use the proposed self-assessment in order to evaluate the management side of the supplier. It is

necessary to identify the type of supplier the SME is, and see what would be the evolution implications for the short, medium and long term in the aerospace industry.

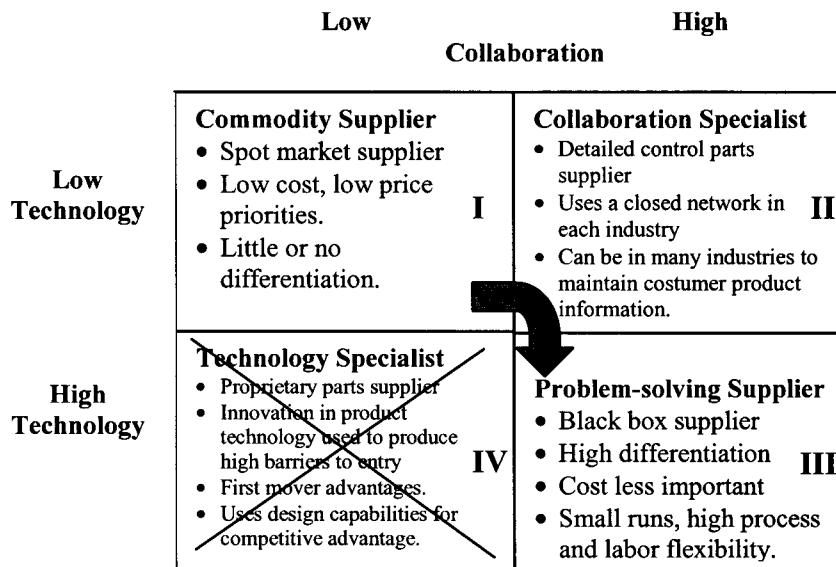


Figure 3-5. Strategic supplier typology. Adapted from Kaufman et al. (2000).

The typology shown in Figure 3-5 is divided along two dimensions: technology and collaboration, and from here they describe 4 types of SMEs. This typology has been adapted in this work to classify the SME and to determine its course during the time of its development. Given the industry nature and the SMEs' opportunity in LCCs as seen in previous chapters, only the first three quadrants are considered useful for this study.

The first quadrant defines firms that use standardized technologies and relate to customers through standard market contracts. These firms compete successfully on the basis of low cost: investments in advanced technologies and managerial practices not always can be fully recovered. Neither customers nor suppliers are dependent because switching costs are low. Parts are designed and manufactured to be sold 'out of the catalogue' to a generic customer. Firms in this quadrant are labelled *commodity specialists*. Here is where most of the Mexican SMEs could be placed now, but the aim is to become an aerospace supplier. Certainly, it is necessary to implement a process to move forward to the next two quadrants.

The second (see quadrant II) group of firms use standardized technologies (general assets and skills) to make parts which meet customer specifications and delivery schedules. These



firms develop enhanced, collaborative techniques to fulfill current and to anticipate future customer needs. Because these products remain under their customers' detailed (design) control (Clark and Fujimoto, 1991), suppliers in this quadrant generally invest few resources to innovate in product or process technology, thus avoiding dependency on a few customers. Customers find these suppliers attractive because they reduce internal monitoring (administrative) costs. These suppliers' customers reduce hold-up uncertainty by only outsourcing parts that do not use core manufacturing know-how. These firms are called *collaboration specialists*. This is today's best and nearest option in order to be a successful supplier in aerospace industry as a Mexican SME in the short-medium term, considered by the author of this thesis, and also as a first approach for a company. The second approach would be on the third quadrant.

The third quadrant describes firms that employ both advanced technologies and collaborative methods to promote innovations in product design and manufacture. Firms in this quadrant compete primarily on their ability to continuously acquire and evolve new ways to solve process and product problems. Customers reduce monitoring costs and avoid expensive investments in specific skills and assets. Because these firms become mutually dependent on one another, trust reduces hold-up uncertainty. An example is a producer of complex sub-assemblies. The firms in this quadrant are called *problem solvers*, and it could be the future of successful aerospace Mexican suppliers in the medium-long term climbing up the aerospace supply chain (Tier 4, 3, 2...).

### **3. 1. 3. 2. Joint Resource Provision**

Doing site visits to the supplier, and visits to the buying firm by the supplier's representatives is pretty important to be considered in a supplier development program. Providing joint resources between customers and suppliers is required in terms of: equipment, personnel, training and information systems. A continuous communication between firms is pretty important so that each side can understand in a deep way the specific engineering, manufacturing and procurement practices to be improved. Also the supplier can get information about the different areas where it has been evaluated in order to fulfill customer expectations and achieve the requirements asked. The communication effort must be timely, frequent, even informal, by having a greater number of contacts between the two firms, and

by having a propensity to ongoing exchange of proprietary information. Customers are regarded as an important source of information. A number of possible inter-organizational processes are proposed in Figure 3-6, with a distinction made between engineering activities, SD activities, and procurement activities.

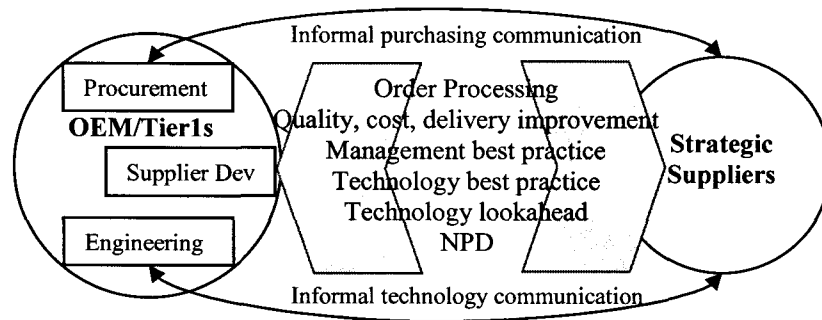


Figure 3-6. Conceptual diagram of inter-organizational processes between system integrators and suppliers. Adapted from Reed and Walsh (2002).

To design a training and education program of the supplier's personnel according to the needs identified in the last stages is a key in the aerospace industry. After having seen the quality practices for a QMS in the aerospace industry, we should figure out the importance of the personnel training to perform manufacturing operations in this industry.

Both the supplier's and customer's sides could then have an idea of the investment in the supplier's operation. Investment is important not only in equipment, but also in training, certification, and other issues. A company needs to invest in new technology, new systems and in human resources. In order to achieve the standards needed, Amado (2007) states that fundamental changes must happen in: a) finance systems: cost accounting, ROI, WIC; b) quality systems: certification, documentation, auditing, continuous improvement; c) manufacturing system: production control, inventory management; c) purchasing system: outsourcing, SCM; and d) HR systems: training, retention, etc.

### 3. 1. 3. 3. Manufacturing Stages Program

To identify the manufacturing stage on which the SME can begin producing aerospace parts or products, the manufacturing capabilities improvement is by a process, as shown in the Figure 3-7. Long-term technological supplier capability is critically important to the future competitiveness of the manufacturing industry. Improving it requires a long-term focus. Each

SME must identify at which stage it is placed or where it could begin within this complex industry.

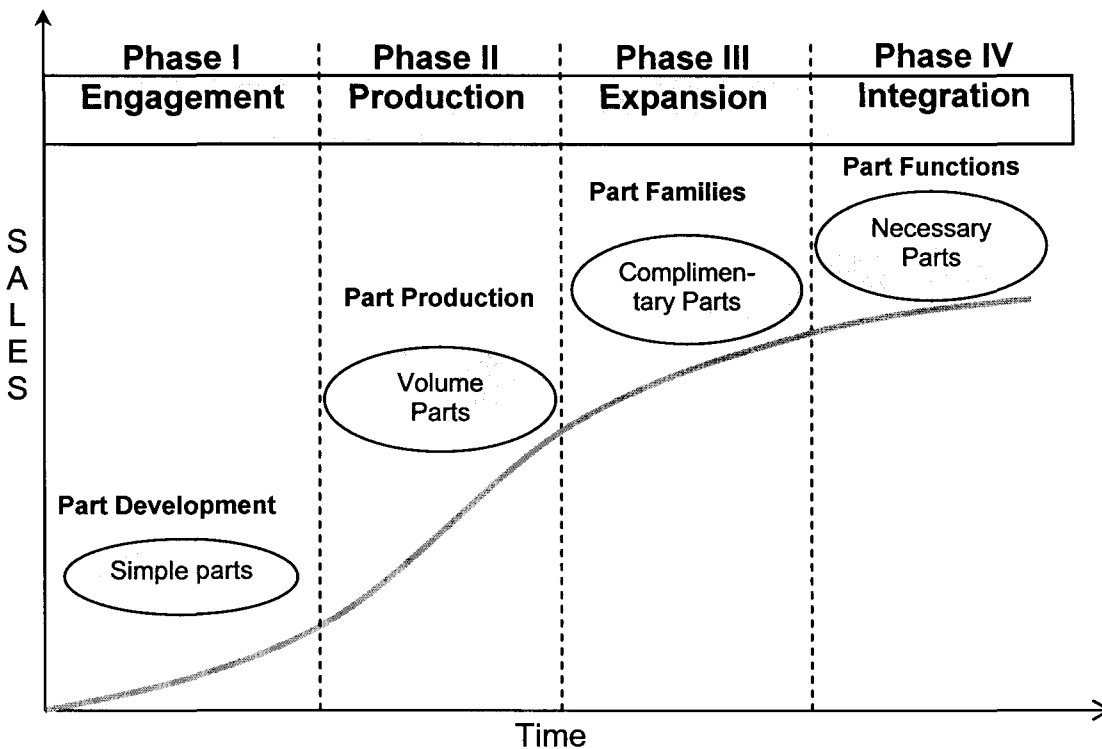


Figure 3-7. Part production evolution phases in the aerospace industry. Adapted from Amado (2007).

Suppliers that begin working for aerospace customers must follow a transition given by different phases or stages to increase sales over time: a) engagement, by producing simple parts using actual manufacture capabilities; b) production, by adding new techniques and capabilities to define part families; c) expansion, by adding value to engineering and manufacturing processes; and d) integration, by producing complete kits or sub-assemblies (Amado, 2007). SCM is step by step, and it takes several months to become a consolidated supplier in this industry given the business complexity.

### 3. 1. 3. 4. Ongoing Continuous Improvement (CI)

To have an ongoing CI for supplier councils, updating goals, supplier measurement, and visible milestones are always needed in the aerospace industry. As stated before, all suppliers shall implement an internal CI Program which may consist of: Lean Manufacturing, Six Sigma, Total Quality Management / Total Productive Maintenance, APQP

methodology, etc. The goal of the program is to eliminate waste and the cost of poor quality and to improve on time delivery. This is also a philosophy that SMEs must have when working as aerospace suppliers. It can be applied by means of supplier councils, updating goals, using supplier measurement tools and visible milestones.

Systematic SD through the use of direct-involvement activities, incentives and rewards, and warnings and penalties is useful at this stage. Techniques for supplier improvement projects may include process mapping, inventory reductions, training, total preventive maintenance, and other joint projects. These techniques can be complemented by the use of award programs and increased business for the best suppliers, which serve as incentives for improved performance.

To maintain momentum is important; appropriate incentives for improvement should be developed to ensure that the improvement effort is not limited to a single process. The supplier must be encouraged to maintain momentum for improvement and to make continuous improvement a part of the company philosophy. The outcome of a successful development strategy is a self-reliant supplier who can initiate its own improvement projects based on performance feedback from the customer.

### **3. 1. 4. Getting Contracts.**

After the supplier has closed the gaps and its processes and certifications are according to general aerospace requirements, it is the time to get more contracts with different aerospace customers. Given the high mix of jobs, this is required to survive in this industry. SMEs must be ready to participate in the following process, which has been described by Morissette (2007) and adapted to this framework.

- i. During a supplier selection process, usually, customers clearly identify the requirements for a program to pick a supplier, and totally communicate all requirements to candidate suppliers.
- ii. SMEs must make project proposals to offer their jobs to an aerospace customer according to the well understood requirements published by customers.
- iii. When a proposal is reviewed by an OEM/Tier1, a recommendation is given to the SME.

Once the customer receives and reviews, such technical and commercial proposals are moved to the perspective areas of the customer for analysis and comments. The short risk is established and sometimes the supplier's support is required to review some information.

- iv. As seen in the first two stages of the framework, SMEs must re-work the indicated areas in order to fulfill the requirements established from the beginning.
- v. Then, negotiation compliance matrices are closed and afterwards comes the final selection review and other team recommendations. Recommendations and actions are given to the SME to be completed before award.
- vi. In a selection review meeting, the OEM/Tier one special team reviews the product family strategy and the current market feedback analysis (MFA) for that product. Sourcing activities are remembered. Also usually a supplier comparison is done about the contractual, technical, aftermarket, productivity and business evaluation conditions.
- vii. Then a deeper risk assessment is applied to the supplier (see section 2.3.3).
- viii. Finally, some conclusions and recommendations (pros and cons) are suggested as actions (checklist) to be completed before award.

### **3. 1. 5. Getting Outcomes.**

Here comes a new stage for a SME getting extension of ongoing business and new business. It is important to know that award is only given when all documents are negotiated to satisfaction. When documents are not complete, conditional award can be given upon satisfactory completion. Finally, in this stage, the contract is signed (internal OEM process) and the MFA competition information is captured for future reference (Morissette, 2007). At this point of the framework, rewards and recognition for achievement are obtained by the supplier. Suppliers get new awards which are really deserved after all the previous process. Certification is given to the supplier. It is pretty important in aerospace where, as stated before, many customers are inter-connected. There is a lot of collaboration; so, being a good

customer's supplier means reliability to other customers and it makes the SME go forward to get more contracts with other companies within the aerospace industry.

SMEs can find the outcomes described below while working for aerospace customers and continuing working for others industries. They will improve their processes and their quality with better practices, better capabilities, and better management.

- Higher market projection to all aerospace customers. A small proportion of Mexican suppliers have AS9100B certification.
- Secure long-term contracts.
- Aerospace industry is stable, has a constant demand, has secure contracts, and has fidelity to reliable suppliers.
- High margins rely on the value added of the product, because it could be given as a percentage of the total cost of production (processes).
- Increased quality, flow through materials, procurement features, etc.

### **3.2 Self-assessment Tool**

As indicated in the introduction of this chapter, here is presented the self-assessment tool used to simply, but effectively evaluate candidate and potential aerospace suppliers.

It is essential for Mexican manufacturers to establish a high-level of trust and cooperation with suppliers. The buyer-supplier relationships should move towards maintaining long-term partnerships and quality-oriented sourcing (Fredendall, 2001; Yeung and Chin, 2004). The key to establishing a close bond is to achieve common goals and to create mutual trust with suppliers (Zaheer et al., 1998). Moreover, it is imperative for manufacturers in Mexico or elsewhere to manage suppliers and measure their performance using a self-assessment approach. Self-assessment is a comprehensive, systematic and regular review of an organisation's activities that result in planned improvement actions (Pun, 2002).

This self-assessment tool was created from the information obtained with the research done with different OEM/Tier one companies and actual suppliers in North America using a questionnaire by interview (see the questionnaires in appendixes V, VI and VII), recent

documents reviewed in the literature review of this document, and the differences between the ISO9001 and AS9100B (see appendix IV). The self-assessment tool is focused on the first two main stages of the presented framework: a) knowing the requirements and b) identifying opportunity areas. It is also only oriented to the managerial side, as stated before. The scope of this study is limited to the five main management areas of an SME seen in Figure 3-8. This assessment will be applied to a group of selected Mexican SMEs. In each question the company will answer choosing only one of the four options: 1) totally agree, 2) partially agree, 3) rarely (not often) agree, 4) completely disagree (or: yes always, yes sometimes, almost never, never).

The self-assessment applied in the case study is shown in appendix VIII, it is available and can be downloaded from the followings web pages, in order to be used to assess more SMEs in Mexico: <http://e-hub1.mty.itesm.mx/aerospace/> and/or <http://homepages.mty.itesm.mx/al278912/>. It has 5 main management areas and each of these sections has different sub-sections (see figure 3-9), which were obtained from the main structure of the QMS “deltas” between ISO and AS standards (Sedlak, 2006) and from Chambers et al. (2007) document structure.

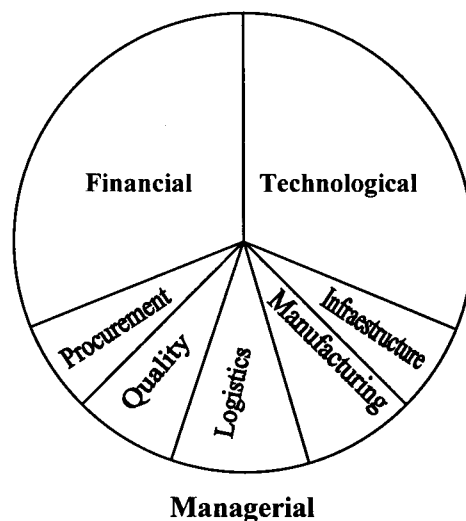


Figure 3-8. Five main management areas to study in a SME.

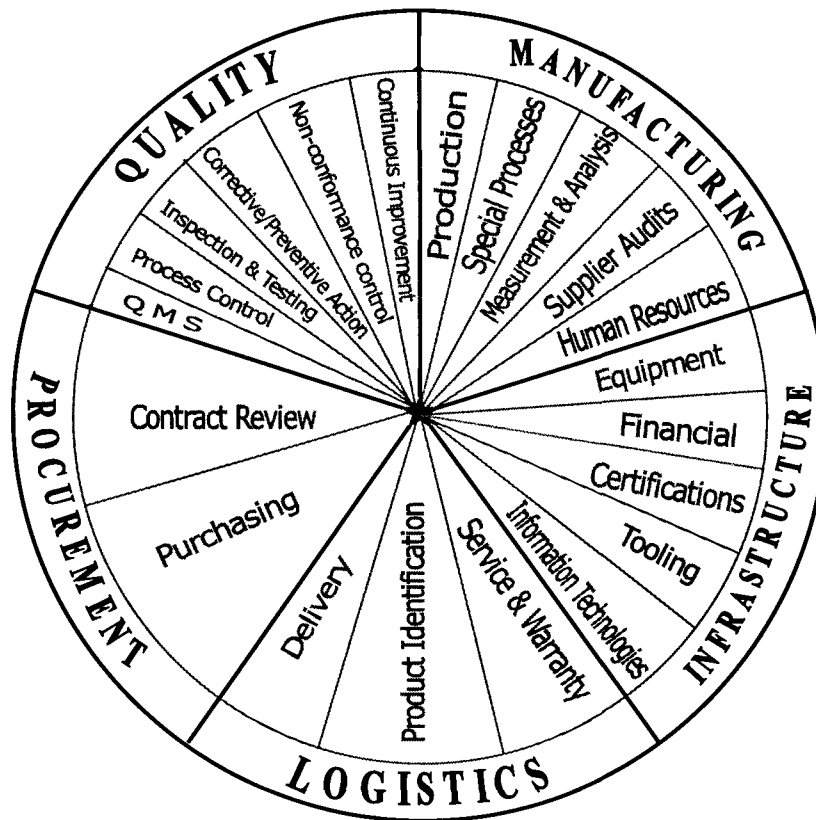


Figure 3-9. Important management areas and their main sub-sections where SMEs need to work in order to become qualified aerospace suppliers.

In each management area and its sub-section of this tool, SMEs are auto-assessed and qualified according to their performance on each subject with a simple and standard scale from 1 to 4 (being 4 the best and 1 the worst). All these sections and sub-sections are averaged as follows: in blue boxes is the average of each group of questions, in yellow boxes is presented an average of all questions within a sub-section, and in green boxes the average of the complete management area. Then, each general section is taken to build a radar chart taking the results of each management area, which is an easy way to detect the important areas that must be considered in order to fulfill aerospace customer requirements according to this study. Each sub-section is also plotted to detect the specific management practices that need improvement. On each radar chart the author of this thesis considers that the minimum accepted value is a 3 (which still needs improvement), and the ideal is a 4 (SME fulfills the requirements). For instance, it is possible that a supplier which is in the process of getting an aerospace certification from a customer, recognized association or



institution, can be taken into consideration in a quoting process, and could even begin working for certain aerospace customers, i.e., producing non-critical parts. So, an answer of 3 is understood that the SME partially fulfills the requirement and is in a process of achievement. A 2 or 1 would need direct improvement if the SME wants to become a qualified aerospace supplier.

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## CHAPTER 4

### 4. CASE STUDY

This chapter deals with a Case Study in which the thesis proposal was applied. The case study has been developed within Mexico's Metalworking Manufacturing Sector. This case is related with the qualification process of three Mexican SMEs (Companies A, B and C) which would like to become consolidated aerospace suppliers. The main purpose of the development of this case is to apply the first three stages of the proposed framework by using the self-assessment created. It lets the SMEs know the nature of the industry and the requirements, it evaluates them according the topics seen in the previous chapters, and it proposes a development process plan according to the identified opportunity areas and gaps. The application of the supplier development practices and the last two stages of the framework (getting contracts and getting outcomes) could be done in further case studies, but here only how companies in North America have followed the proposed methodology is described.

The main objectives of the case study are: 1) to identify the most critical areas in the management side where SMEs must work, 2) to classify them according to their management capabilities, 3) to propose a development plan in collaboration with aerospace OEMs/Tier ones, and 4) to show them the stages that actual suppliers follow in order to get customers contracts and awards in the aerospace industry.

*Company A* has been a Metal Mechanic, Aluminum and Steel Products producer for more than 20 years, and currently works for architectural, lighting industries, truck and trailer industry, appliances, telecommunications, electric industries, etc. This company possesses the following main capabilities: tube, bar, plate, angles, industrial coil/strip, white and roof-coil sheet for truck and trailer industry, threadbrite aluminum. *Company A* supports the following services: cutting, welding (TIG/MIG), drilling, stamping, bending, rolling, tapping, and others. As we can see, it is the type of company that aerospace customers are looking for with metal parts production, structures, components, and others. This company is willing to open a new aerospace division in a new facility and wants to know more about the aerospace industry opportunity as a market, its requirements, practices, infrastructure, and all the topics shown

inside this document.

*Company B* is an SME of Systems Engineering that makes tools, dies and molds with knowledge in tools and machining as a competitive advantage, in addition automation and industrial control by producing high precision components for heavy industry. This company has new visions with components of the aerospace industry market to which they have been recently attracted and have quoted several packages competitively. *Company B* is also trying to increase equipment and facilities to give a better expectation and control of the processes. This company is enhancing its QMS as well. Its oriented values are: six sigma green belt certified, lean manufacturing oriented approach, high automated and controlled processes, broad project development and administration, academy support and development, and its CAD/CAM/CAE/FEM capabilities. Its main customers are from automotive and electric industries. This company is willing to develop a resource for aerospace and technology, demanding manufacturing and highly skilled technical people in its region for the coming years.

*Company C* is the third Mexican SME studied in this research work. It began operations around twenty years ago and currently serves metalworking industries such as: automotive, textile, pharmaceutical, and few months ago has been trying to enter into the aerospace sector. *Company C* is specialized in CNC machine services for gears, molds, arrows, and other devices. It is a company committed to quality, maintenance, technical innovation in processes, which has ISO 9001:2001 as a QMS certified. This company also works processes covering arc spray for metals and stainless steel equipment manufacturing. *Company C* is willing to continue performing aerospace jobs and to increase the number of orders and customers; so, it is trying to transform its QMS into an aerospace one (AS9100B). They could get certified by next year according to their plans.

#### **4.1 Specific Objective**

The specific objective of this chapter is to demonstrate how the proposed methodology is implemented in Mexican companies which can then define and follow its own path to become aerospace suppliers according to their own characteristics and needs.

## **4.2 Demonstration Scope of the Framework Application**

In the supplier qualification process for the aerospace industry, some issues are considered. In this case the framework is applied mainly to improve the management practices of the company with a quality approach. The framework only partially considers technological and financial aspects because they mainly depend on a specific product or facilities for that product or family of products. The tools of this framework have been used by North American companies. The framework application effectiveness, in low cost regions, needs still to be proved in the stages: knowing the requirements, getting contracts, getting outcomes, and the application of the stage “closing gaps” needs to be developed as well.

## **4.3 Case Study applied to Companies A, B, and C.**

### **4.3.1. Knowing the Requirements**

This case study doesn't cover the “knowing the requirements” process, since the three companies studied were already aware of the aerospace industry characteristics seen in the last three chapters of this thesis. Company A has managers well trained in aerospace topics, who know about the differences between this industry and others. Company B has begun trying to make quotations for aerospace customers and has been visited by some of those future customers and their managers. Company C has begun quoting jobs for aerospace customers a few months ago and is probably performing a small number of jobs with the promise of getting their AS9100 certification during the following months. We can assure that these three companies have been getting information about the aerospace requirements and the nature of the industry. They have even been following the evolution of this study and cooperating with useful information through at least a period of eight months.

### **4.3.2. Identifying Opportunity Areas**

The self-assessment was applied to these three companies and here are shown the results. As stated at the end of chapter 3, the self-assessment application (see appendix VIII) and calculation was done by the following process: 1) the company received the questionnaire, and answered it; 2) once the results were obtained, the calculations were done for each management topic and its subsection by getting the average in each group of questions as shown in the tables listed below; 3) a radar chart was plotted for each group of results to easily see the SME behavior.

## Company A

|                                |      |
|--------------------------------|------|
| <b>3-A-1. Quality</b>          | 2.51 |
| Quality system                 | 2.58 |
| Process control                | 2.50 |
| Inspection and testing         | 2.50 |
| Nonconforming product          | 2.75 |
| Corrective / Preventive action | 3.00 |
| Continuous Improvement         | 1.75 |

|                           |      |
|---------------------------|------|
| <b>3-A-2. Procurement</b> | 2.71 |
| Contract Review           | 2.75 |
| APQP/Control Plan         | 2.00 |
| Manufacturing plans       | 2.00 |
| FMEA method               | 3.00 |
| Offload/transfer of work  | 3.00 |
| Flowdown                  | 3.00 |
| Purchasing                | 3.20 |

|                             |      |
|-----------------------------|------|
| <b>3-A-3. Manufacturing</b> | 2.20 |
| Manufacture                 | 2.19 |
| Special Processes           | 2.67 |
| Measurement and Analysis    | 2.50 |
| Supplier Audits             | 2.17 |
| Human Resources             | 1.50 |

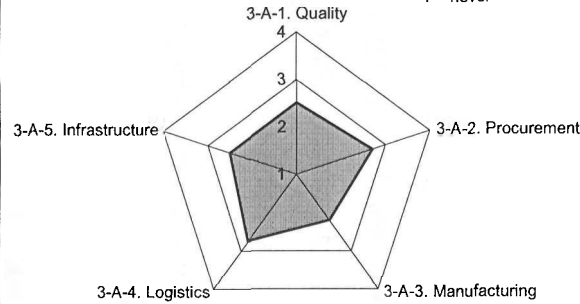
|                         |      |
|-------------------------|------|
| <b>3-A-4. Logistics</b> | 2.75 |
| MTO                     | 3.50 |
| Delivery                | 3.00 |
| Preservation of product | 3.00 |
| Product identification  | 2.00 |
| Service and warranty    | 3.00 |

|                              |      |
|------------------------------|------|
| <b>3-A-5. Infrastructure</b> | 2.50 |
| Certifications               | 2.33 |
| Tooling                      | 2.00 |
| Information Technologies     | 2.67 |
| Financial related            | 3.00 |

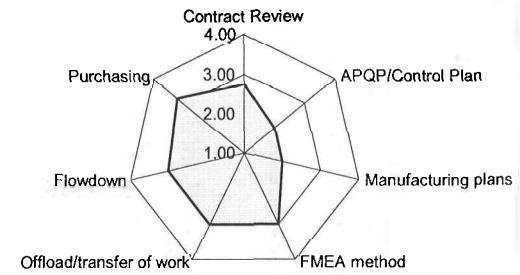
|                                |      |
|--------------------------------|------|
| <b>3-A-6. Management Areas</b> |      |
| Quality                        | 2.51 |
| Procurement                    | 2.71 |
| Manufacturing                  | 2.20 |
| Logistics                      | 2.75 |
| Infrastructure                 | 2.50 |

3-A-6. General Gap Analysis

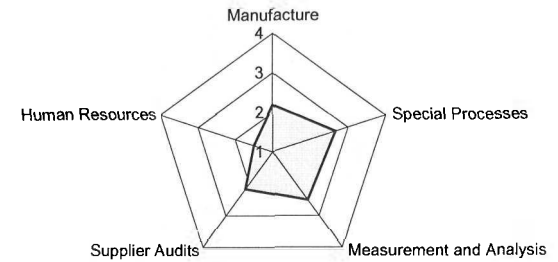
4 = Always  
3 = sometimes  
2 = almost never  
1 = never



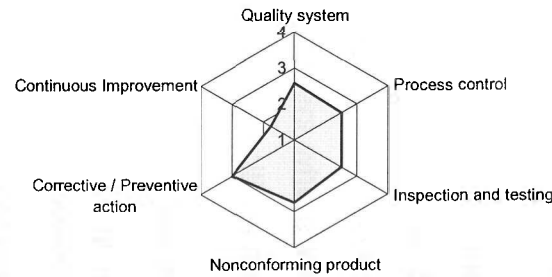
3-A-2. Procurement



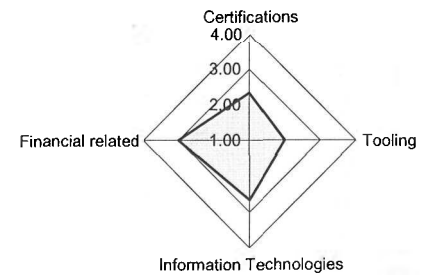
3-A-3. Manufacturing



3-A-1. Quality



3-A-5. Infrastructure



3-A-4. Logistics

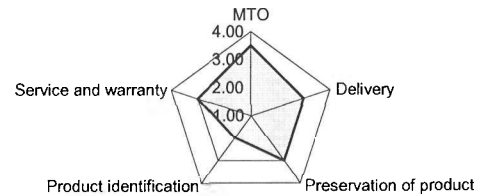


Figure 4-A-1. As we can see on the last page, company A is missing a certified QMS which is essential in the aerospace industry. Their quality standard is based on customer satisfaction by performing corrective and preventive actions to deliver good quality products. This company is working to get ISO certification, and getting it would be a first step. Process control, inspection and testing are basic quality practices that every metalworking company must have in this industry. An implementation of continuous improvement (CI) tools having a CI philosophy is a must as well.

Figure 4-A-2. In this figure it is clear that Company A needs improvement in manufacturing planning and APQP control plans because, as seen in the previous chapters, these practices benefit directly the procurement process with a customer when a high mix of jobs is financially useful. In the other sub-sections of procurement, this company looks well and its sales demonstrate other management skills inside its procurement with its actual customers. However, this is an area that company A must enhance as a future aerospace supplier.

Figure 4-A-3. Manufacturing with a QMS approach is the weakest area of company A. Employees' training is an important issue because they need to be certified. Planning, control of equipment operations and changes, production documentation are necessary for this company while working for aerospace customers where value added to products is higher. Measurement and analysis inside and outside its facilities also needs improvement.

4-A-4. The logistic area is the strongest one that company A has in place. This is a company which works on a make to order basis with a relatively high mix of customers. Delivery, preservation of product, service and warranty are its principal competitive advantages, and according this study are competitive attributes for aerospace. However, their performance would be enhanced once the SME is QMS certified when a part making and serialization system would be implemented.

Figure 4-A-5. This SME has a good financial health with high sales and investment capacity to become an aerospace supplier; this is one of its strengths. Cash flow and inventory rotations are opportunity areas where aerospace suppliers often have strength. This company would need to strongly invest in capabilities such as machines, tooling, certifications, information systems, etc. Maintenance and/or tool repair records are other

important issues to keep in mind.

Figure 4-A-6. In a general overview we can see that this company is balanced in its performance. Its weaknesses, according to aerospace requirements, principally rely on the lack of a robust QMS, which would enhance their performance in different areas mainly regarding manufacturing. This company has good financial health compared to others and has good high level management. These represent important strengths according the literature.

## Company B

|                                |             |
|--------------------------------|-------------|
| <b>3-B-1. Quality</b>          | <b>3.77</b> |
| Quality system                 | 3.83        |
| Process control                | 4.00        |
| Inspection and testing         | 3.29        |
| Nonconforming product          | 3.75        |
| Corrective / Preventive action | 4.00        |
| Continuous Improvement         | 3.75        |

|                           |             |
|---------------------------|-------------|
| <b>3-B-2. Procurement</b> | <b>3.37</b> |
| Contract Review           | 4.00        |
| APQP/Control Plan         | 4.00        |
| Manufacturing plans       | 2.00        |
| FMEA method               | 4.00        |
| Offload/transfer of work  | 2.00        |
| Flowdown                  | 4.00        |
| Purchasing                | 3.60        |

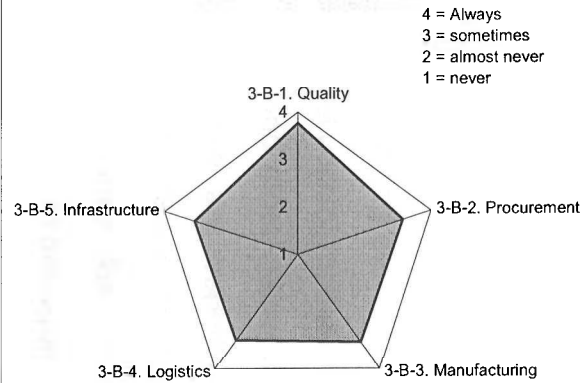
|                             |             |
|-----------------------------|-------------|
| <b>3-B-3. Manufacturing</b> | <b>3.31</b> |
| Manufacture                 | 3.88        |
| Special Processes           | 3.67        |
| Measurement and Analysis    | 4.00        |
| Supplier Audits             | 3.50        |
| Human Resources             | 1.50        |

|                         |             |
|-------------------------|-------------|
| <b>3-B-4. Logistics</b> | <b>3.25</b> |
| MTO                     | 3.00        |
| Delivery                | 3.00        |
| Preservation of product | 4.00        |
| Product identification  | 4.00        |
| Service and warranty    | 2.00        |

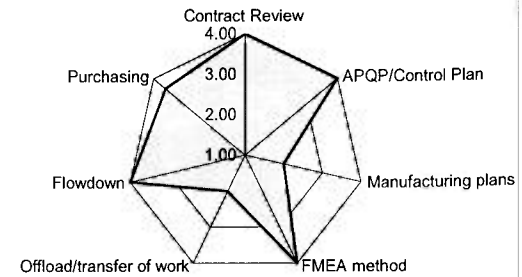
|                              |             |
|------------------------------|-------------|
| <b>3-B-5. Infrastructure</b> | <b>3.33</b> |
| Certifications               | 3.56        |
| Tooling                      | 3.67        |
| Information Technologies     | 3.33        |
| Financial related            | 2.75        |

|                                |             |
|--------------------------------|-------------|
| <b>3-B-6. Management Areas</b> |             |
| <b>Quality</b>                 | <b>3.77</b> |
| <b>Procurement</b>             | <b>3.37</b> |
| <b>Manufacturing</b>           | <b>3.31</b> |
| <b>Logistics</b>               | <b>3.25</b> |
| <b>Infrastructure</b>          | <b>3.33</b> |

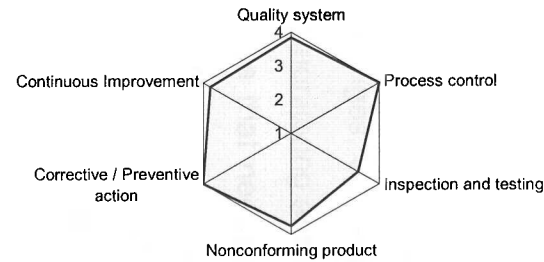
3-B-6. General Gap Analysis



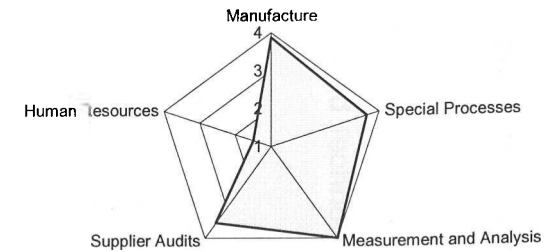
3-B-2. Procurement



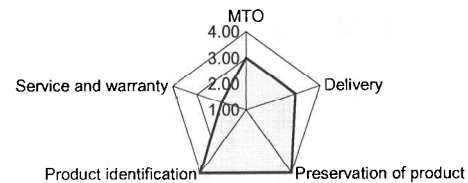
3-B-1. Quality



3-B-3. Manufacturing



3-B-4. Logistics



3-B-5. Infrastructure

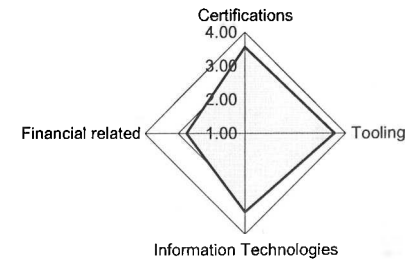




Figure 4-B-1. As we can see in this chart (on last page), company B has good quality practices and it is its principal competitive advantage. As stated above, this company is applying for ISO certification and is really prepared to get it. However, there are some areas they could be improved for instance, purchased product inspection, sub-supplier control, documenting verification and testing, control of non-conforming products as well as high precision, high value added in products, good technological capabilities which cause good quality in its products.

Figure 4-B-2. This company has in general good procurement practices, but has some issues to solve before becoming an aerospace supplier. Company B fits in aerospace because its business nature agrees with its strengths, it is able to get long-term contracts, and it seems to be prepared to take orders from customers. Company B is good at making quotations and interpreting drawings because it has good engineering expertise supported by an APQP control plan. This company has opportunity areas mainly recording manufacturing planning of its components, and also managing and controlling sub-suppliers.

Figure 4-B-3. Manufacturing regarding its QMS is outstanding in its operations planning, producing, offering service, documenting changes, etc. Also, this company is very strong in its statistical control methods and control of monitoring and measuring devices. Although, this is the second most critical management area that needs improvement in company B. It is because there are opportunity areas in human resources; this company needs better management skills in middle-low levels and certified workers to perform some jobs that aerospace requires. Also, company B must implement an internal and external audit system, which is relevant in aerospace, not only controlling quality in-house but even sub-tiers.

Figure 4-B-4. Logistics is the weakest area of company B. According to this assessment its performance is approved, but it still needs improvement. Product identification practices are detected as a strength factor. This company is able to work on a MTO basis, although it would be a challenge because of the difference between working for automotive and aerospace customers. It is necessary to increase the number of parts, the mix of customers, to faster set up machines, etc. Also a better delivery performance is needed. This is a critical performance indicator. Service, warranty and controlling suppliers are important issues to

consider as well.

Figure 4-B-5. Company B has a good infrastructure because it is near to getting ISO and TS certifications, and that is a reason for its good quality assessment results. Also this company has good technology capabilities in engineering software, machines, etc. The gaps identified are to enhance its ERP/MRP system capabilities because having more customers, more part numbers, and more mix of products in aerospace would be useful. The other important section is financially related. This company has a poor cash flow and low sales, but good inventory rotations and investment capacity.

Figure 4-B-6. Procurement, logistics practices, middle-low level management and employee's certifications need improvement to get more customers, more parts, and as a consequence better financial health. Quality, certifications, equipment, technological capabilities and engineering expertise are strengths identified in company B.

## Company C

|                                |             |
|--------------------------------|-------------|
| <b>3-C-1. Quality</b>          | <b>3.32</b> |
| Quality system                 | 3.77        |
| Process control                | 4.00        |
| Inspection and testing         | 3.14        |
| Nonconforming product          | 4.00        |
| Corrective / Preventive action | 4.00        |
| Continuous Improvement         | 1.00        |

|                           |             |
|---------------------------|-------------|
| <b>3-C-2. Procurement</b> | <b>2.14</b> |
| Contract Review           | 2.25        |
| APQP/Control Plan         | 1.00        |
| Manufacturing plans       | 3.00        |
| FMEA method               | 4.00        |
| Offload/transfer of work  | 1.00        |
| Flowdown                  | 1.00        |
| Purchasing                | 2.70        |

|                             |             |
|-----------------------------|-------------|
| <b>3-C-3. Manufacturing</b> | <b>3.29</b> |
| Manufacture                 | 3.13        |
| Special Processes           | 4.00        |
| Measurement and Analysis    | 4.00        |
| Supplier Audits             | 2.83        |
| Human Resources             | 2.50        |

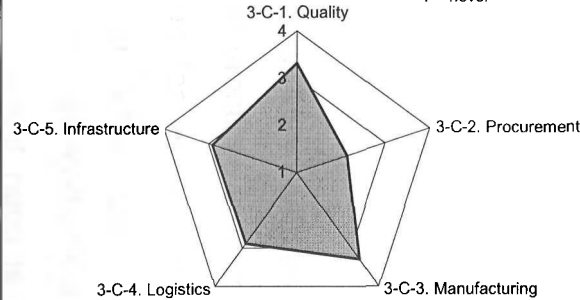
|                         |             |
|-------------------------|-------------|
| <b>3-C-4. Logistics</b> | <b>2.88</b> |
| MTO                     | 3.50        |
| Delivery                | 1.00        |
| Preservation of product | 4.00        |
| Product identification  | 2.50        |
| Service and warranty    | 4.00        |

|                              |             |
|------------------------------|-------------|
| <b>3-C-5. Infrastructure</b> | <b>2.91</b> |
| Certifications               | 2.89        |
| Tooling                      | 3.67        |
| Information Technologies     | 2.33        |
| Financial related            | 2.75        |

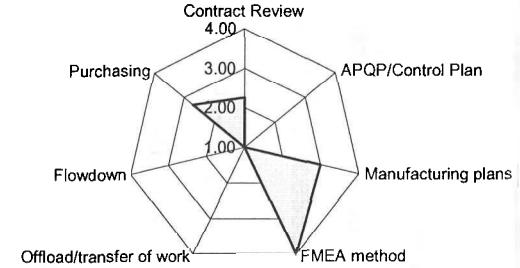
|                                |      |
|--------------------------------|------|
| <b>3-C-6. Management Areas</b> |      |
| Quality                        | 3.32 |
| Procurement                    | 2.14 |
| Manufacturing                  | 3.29 |
| Logistics                      | 2.88 |
| Infrastructure                 | 2.91 |

### 3-C-6. General Gap Analysis

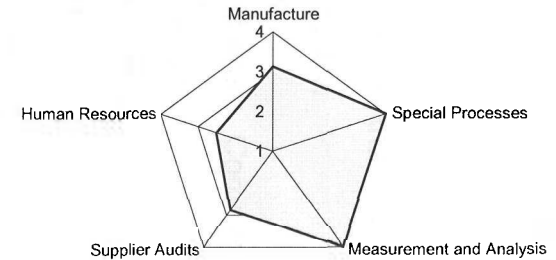
4 = Always  
3 = sometimes  
2 = almost never  
1 = never



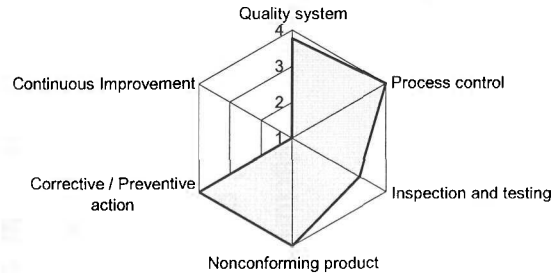
### 3-C-2. Procurement



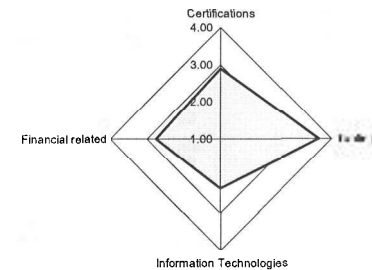
### 3-C-3. Manufacturing



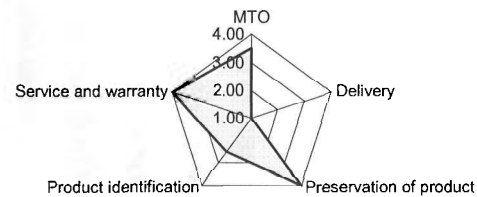
### 3-C-1. Quality



### 3-C-5. Infrastructure



### 3-C-4. Logistics



### **Company C**

Figure 4-C-1. Company C has excellent quality practices since it is ISO9001 certified. Its practices are according to its QMS, but this company could improve its sub-supplier control to evaluate delivery times and quality, control and record aspects of verification and validation testing. The other gap identified is that it does not have a continuous improvement program which is necessary in this industry.

Figure 4-C-2. Procurement is a critical area. Company C must work on its QMS in order to become a more successful aerospace supplier. It is relevant that company C has a good purchasing system, and that it uses a method to identify potential failure modes for each critical part and its processes (FMEA). On the other hand, this company needs improvement in documentation of process changes and in the review of product requirements. It needs a pre-planning method for new parts, to get a better control of its suppliers' quality, to implement a verification of purchased product, and to have a raw materials testing method. Company's sales can be increased by having a more reliable procurement system and more customers can be attracted once this company gets AS9100 certification and closes its performance gaps.

Figure 4-C-3. This company has excellent manufacturing practices and has a QMS. They have good practices in their special processes and could be a strong candidate to achieve certification for working in the aerospace industry in the near future. This organization maintains good management practices at different levels, has an internal audit system, uses statistical control methods and has a control of monitoring and measuring devices. What company C would need is to implement a system to control the work transferred on a temporary basis, outside the organization's facilities, to certify workers and also to produce records of its internal audits. These are areas to work on in order to achieve AS9100 certification.

Figure 4-C-4. This company is also able to work and actually is working on an MTO basis, and could get a higher number of customers once getting aerospace certification; so, it is considered a potential supplier. This is an SME that has good practices in product preservation, product identification and traceability, service and warranty. Improvements are

required in delivery, part making and serialization.

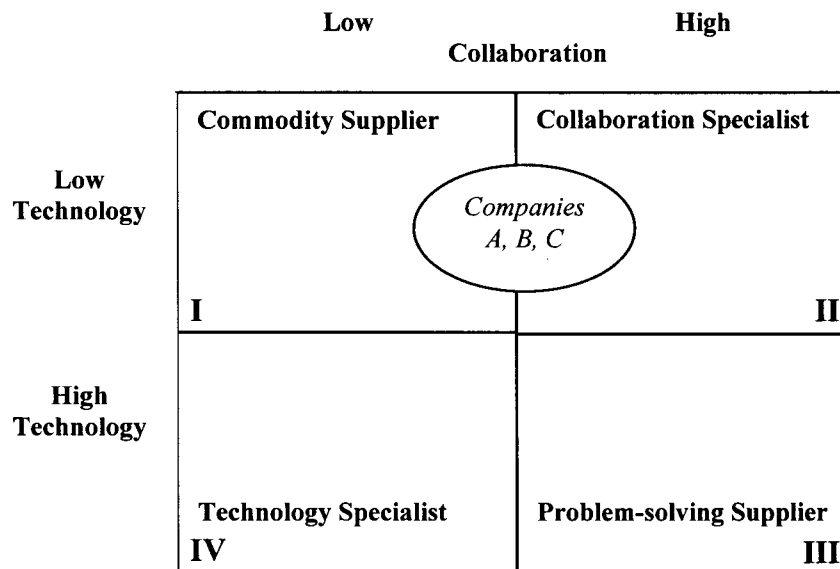
Figure 4-C-5. Company C practices and records tool maintenance according to customer requirements and also produces its own tooling capabilities. Also, as mentioned before, this company is planning to get AS9100 certification next year. The opportunity areas are in getting information technology systems that would support its procurement and logistics which are the weakest ones. The financial area could be improved as well, and it certainly depends on other areas. Procurement and logistics can be helpful to increase sales and cash flow, and inventory rotations of this company have been identified as opportunity areas too.

Figure 4-C-6. The good QMS implemented in company C impacts positively and directly the manufacturing area. Logistics must be improved because delivery is one of the three main evaluation factors aerospace customers do measure. A good procurement system supports the logistics operations and the financial health. This company needs to be prepared to receive more orders, to increase its inventory rotations and to increase its sales because once having AS9100 certification more markets will be opened for company C.

### **4. 3. 3. Closing Gaps**

The three companies studied require improvement in areas seen in the last section. Development practices appropriated to SMEs in the aerospace industry were presented and suggested. They will allow each of them to more quickly get better performance when working with their future customers. In this section supplier development planning using a strategic approach was shown in order to achieve higher performance relative to prior performance levels and to have the most successful development initiatives to increase supplier areas such as cycle time, quality, total cost, delivery, responsiveness, etc.

### 4.3.3.1. Supplier Performance Analysis



According to the definition given in section 3.1.3.1., the three studied companies can be classified between commodity supplier and collaboration specialist. It is a spot market supplier that produces in a low cost structure having low price priorities and little or no differentiation. These SMEs are also in part a collaboration specialist because they work for different industries. A path could be to first completely become a collaboration specialist in the middle term, and finally, a long-term vision could be working as a problem-solving supplier.

### 4.3.3.2. Joint Resources Provision

Direct involvement of personnel is undoubtedly the most challenging part of supplier development. Not only must internal management and employees be convinced that investing company resources in a supplier is a worthwhile risk, but the supplier must also be convinced it is in its best interest to accept direction and assistance. Even if mutual understanding of the importance of supplier development is reached, there is still the matter of making it happen. Effective supplier development requires the commitment of financial, capital, and human resources, skilled personnel, sharing of time and accurate information between the customer and the supplier, and timely performance measurement. Notice that none of these companies necessarily have to make a partnership with another company, they have three ways to choose when making strategic decisions: a) to invest in their opportunity

areas in order to follow the framework and become qualified aerospace suppliers, b) to make a partnership with a company that best fit in their processes according the partner strengths and the SME gaps and become qualified, and c) don't try to become aerospace supplier because of the structure needed to be profitable.

**Company A.** As a technological partner it would be useful to improve its QMS and equipment. This SME needs to get a more robust QMS that will allow better manufacturing practices. Also this company needs to decide what kind of equipment would be the best choice according to the market they will have in aerospace. This is a balanced company with good management and these practices could flow down to all levels. Training of its personnel will be an important instrument. Areas where there is a need for joint resource provision are:

Quality: quality system, process control, inspection and testing, nonconforming product, continuous improvement.

Procurement: contract review, APQP/Control Plan, manufacturing plans

Manufacturing: manufacture, special processes, measurement and analysis, supplier audits, human resources.

Logistics: product identification.

Infrastructure: certifications, tooling, information technologies.

**Company B.** An administrative partner and a capitalist partner would be useful for company B. It is because its opportunity areas are mainly in logistics, procurement and in financial related topics. Areas where there is a need for joint resource provision are:

Procurement: manufacturing plans, offload/transfer of work.

Manufacturing: human resources.

Logistics: delivery, service and warranty.

Infrastructure: information technologies, financially related.

**Company C.** From the point of view of this thesis' author, this company does not really need a partner, but, if a partnership were made, the suggestion would be to get a capitalistic partner that would support company growth. Areas where there is a need for joint resource provision are:

Quality: inspection and testing, continuous Improvement.

Procurement: contract review, APQP/Control Plan, offload/transfer of work, Flowdown, purchasing.

Manufacturing: supplier audits, human resources.

Logistics: delivery, product identification.

Infrastructure: information technologies, financially related.

#### **4. 3. 3. 3. Manufacturing Stages Program**

The three companies can begin on the engagement phase, and must follow a manufacturing stages program. Here is presented an evolution that they could follow in order to understand that it takes time to be developed and that in their development process they could define milestones according the following description.

I. Engagement phase, producing simple parts. Suppliers are working on part development in travelers, tooling, materials, part processing, process standardization, purchasing material. All parts can be within a supplier's current manufacturing capability. In this stage the supplier becomes familiar with the customer (specifications, requirements, systems). The excess inventory is useful to provide cash flow and transition.

II. Production phase, increasing volume of parts. Supplies begin part production in family definitions, optimization of lot sizes, process control, demand management, material. Suppliers may apply new manufacturing techniques or add new capabilities. Key parts provide steady cash flow without excess inventory.

III. Expansion phase, complimentary parts. Suppliers work on part families using pull systems, adding engineering value, improving processes, aggregating material. Here are two



approaches to take in consideration: to produce new parts within capabilities or expansion into new processes.

IV. Integration phase, necessary parts. Suppliers work on part functions, for instance, kit / subassembly definition, sub-tier management, supplier development. Parent, key parts assigned. Components can be made or purchased.

#### **4. 3. 3. 4. Ongoing Continuous Improvement (CI)**

Once a development project has been initiated, progress must be monitored and tracked over time. Moreover, an ongoing exchange of information is needed to maintain momentum in such projects. This can be achieved by creating visible milestones for objectives, updating progress, and in turn, creating new or revised objectives based on progress to date. Project planning may require modifications to the original plan, additional resources, information, or priorities depending on events.

All companies in aerospace must have a continuous improvement philosophy in their processes. Improvements in reducing costs, delivery times, quality in reliable products, these are the main aspects evaluated by customers in this industry. SMEs must implement CI programs using tools to flow down CI practices at all company levels as stated in section 3. 1. 3. 4., and in the literature review of this document.

#### **4. 3. 4. Getting Contracts and Getting Outcomes.**

The last two stages of the proposed framework cannot be implemented in this case study of the three studied companies. In chapter 3 a methodology was proposed that has been used by OEM and Tier 1 suppliers in North America. This methodology will serve the studied companies as important information when trying to get contracts with aerospace customers.

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## CHAPTER 5

### 5. RESULTS, CONCLUSIONS, ADDITIONAL OBSERVATIONS AND FURTHER RESEARCH

#### ***Results***

The following results were achieved in the development of this research.

- It was discovered that companies in Mexico had a lack of understanding about the aerospace industry, given its actual and future growth and the customer need for capable suppliers. This study was found useful by aerospace customers and potential suppliers. Useful information about the nature of the industry, certifications, evaluation and measurement tools, conditions, etc., for Mexican companies was published in this document.
- A framework for the qualification process of SMEs for the aerospace industry was defined based on literature review and the background of this work.
- Demonstration of how the methodology can support the qualification process by means of gap identification, and the paths defined according to the aerospace requirements throughout three studied companies.
- A Case Study described in the previous chapter was developed to validate the research ideas and proposals. It showed the following results: a new method or technique was created to assess SME performance; three examples demonstrated the use of the assessment tool.

#### ***Conclusions***

The common main problem found in Mexican SMEs was really the management culture, how SMEs are going to beat on proposals, contracts, etc., a real understanding of how companies do business in the aerospace industry, and how to invest, in what areas they need to do it according their capabilities having a good plan and following the proposed framework. Being the management attitude an important issue, SMEs need skilled managers at all their organization levels. Government, academy and SMEs can make help each other by updating

managers in aerospace industry management related topics (i.e.: financial accounting, QMS, procurement operations, drawing interpretation, etc.) For instance, short-term courses, seminars, workshops, training centers would be very useful to get this information to these Mexican SMEs.

Mexican SMEs are waiting for more contracts to increase the mix of products and mix of customers which can increment their sales and revenues to become more profitable in the business and to get the investment returns.

Mexican suppliers need to spend money in parts development, certifications (AS9100, Nadcap) or technical skills which North American companies already have. Productivity, manufacturing, and other low costs such as electricity, are still making Mexico attractive to American companies. Special programs supported by the Mexican government and OEMs must be implemented to get SME the required certifications because low volumes make it difficult to get returns.

These Mexican companies are demanding highly capable workers, because in machining and other jobs, the suppliers need to know how to use the machines, to get the tolerances, which means that to work on training is relevant, to invest in the people is the key to make it happen, and the future will be for updated companies. One question is the financial risk, but the other is the education in terms of quality systems, quality control, continuous improvement, and manufacturing.

Best management practices are needed. The aerospace industry demands a good management system where managers need to be connected at all levels. Companies in México do not only need to have lower costs due to labor, they need to manage and control other resources such as raw material costs (forecast, availability, etc.) negotiating the service terms, talking conditions, making quotations, etc.

The most significant gaps in Mexican SMEs are: to get a continuous improvement philosophy for all processes, to accomplish the right level of quality expectation and to achieve the experience in the people to meet the expectations of the aerospace industry.

The aerospace industry process conversion for many companies must be step by step. They

will need to begin assembling first, then probably doing the engineering of some parts and then getting closer to their manufacture to start developing features and even the parts along with the development of their engineers. The aerospace supply chain is very complex, México must start with the easiest operations, to begin looking to the entire supply chain, where there is a place for every company.

### ***Additional Observations***

Here are mentioned some important and critical factors to success in supplier development within the qualification process.

Potential suppliers must get a detailed comprehension about the criteria used by the customer to evaluate suppliers. Suppliers must consider all the costs involved in the qualification process. In many occasions, it is necessary to consider capital investment, training, hiring new personnel, etc.

It is important to understand that not all the SMEs have real possibilities for improving their systems and internal policies to begin working in the aerospace market. Many times, it is assumed that the cost of working in México is substantially inferior compared with other countries. This can be false because we should remember that although the manual labor costs are lower in Mexico compared to North American and European countries, manual labor is not the only factor to consider in the total cost of an integrated component.

SMEs must be very realistic consider all variables involved in decision making. It is possible that some companies will not want to get into the aerospace industry, which is perfectly justifiable. SMEs' conversion towards the aerospace industry supply chain is not viable for all organizations.

It is very important to the organizations to create a business plan. Risks related to new customer expectations, new methods introduction, manufacture technologies, and other technological and financial aspects during the supplier qualification process must be considered.

It is necessary to establish clearly what are the benefits in the integration to new markets and

compare them with the associated costs, which could be substantially increased while trying to implement certain changes in QMS, e.g., improving instruments control, measurement and tests systems (AS9100B, element 7.5).

It is important to consider logistic and transportation issues. There is a possibility of realizing certain process stages during the product manufacture process outside the supplier facilities. All terms and conditions must be clearly established with the customer regarding expedition fees, packaging, importing quotes and other fees. The supplier has the responsibility to study, discuss, and in this case, to ask for clarity in order to be sure of the correct customer requirements interpretations on this aspect.

The supplier has to make sure that its personnel skill levels within the organization are correctly evaluated and documented. It is common to see in different types and sizes of organizations that the real personnel training level is inferior to that required.

It is necessary to do an exhaustive revision of the training personal registers to make sure there are no errors; it is not acceptable to declare a person qualified to perform certain job, without assuring by documents, evidence and training records.

It is recommended to perform risk detection studies, using tools (e.g., FMEA) to detect unexpected situations and to use administrative tools to evaluate risks in the business management processes.

It is necessary to establish realistic expectations regarding growth and market conditions. It is common to see that market conditions adjust in an unpredictable approach. For instance, international raw material prices, interest rates, etc., might be impossible to predict exactly because the phenomena which determinate them is out of the organization's control. However, it is possible and highly recommended to prevent, prepare and protect the organization from these effects.

To assure an effective communication between the supplier and buyer people are essential. The organization must take special care about the parties that will be authorized to participate in the negotiations. The technical personnel communication by both parties is critical; continuous communication is required by periodical meetings and by the use of

information technology tools.

### **Further Research**

The author of this thesis recommends this research work to be continued by applying the self-assessment to a bigger group of companies in a region or country. This could bring general results for an OEM or for a government that wishes to detect general gaps in SMEs, and to further work by introducing programs for supplier development. To make this kind of study would probably require the use of statistical tools to interpret and to manage data. The self-assessment was proved as useful to identify possible gaps in SMEs.

In the stage of knowing the requirements (section 3.1.1), there is an opportunity for a further research project, because it's an important issue. This thesis document is only to identify requirements are already understood, however, here have been shown these requirements, but this document doesn't deals with the tools to measure the understanding level of the supplier. So, someone else can develop a check list going deeply to assure that companies understand the industry requirements and characteristics using evaluation tools to assess the comprehension level of the SMEs.

The conceptual supplier development planning methodology was developed to make its execution more efficient. However, a supplier development program should be applied to SMEs in more detail and having more time to see the supplier development results. Then, customers could implement the evaluation tools seen in chapter 2 to assess the supplier improvement in a shorter period. How to get best suppliers in LCCs, once they are producing parts for aerospace customers, is considered as further research.

The application of the last two stages of this framework (*getting contracts, getting outcomes*) was proven with suppliers in North America according the research of this thesis's author. After the application of the first three stages of the proposed framework (*knowing the requirements, identifying opportunity areas, closing gaps*), managers could test the methodology proposed in order to prove the effectiveness of it for Mexican SMEs, having enough time to see the results in their companies.

As seen in this document, the study considered the management aspect of SMEs. It is useful

for SMEs to evaluate other areas such as the financial one. A financial evaluation is needed given the high investment required by an SME when acquiring new manufacturing capabilities, equipment, information technologies, human resources, and even training programs for its personnel. SMEs want to see the pay back periods, if they are financially capable to invest, and other factors related with economy health. A financial model must continue from this study. SMEs' owners and high-level managers need to know what people needs to be hired, what's the cost per hour under a new structure of its company, what's its overhead, if its feasible to enter or not in aerospace industry, i.e. given processes costs per hour, SMEs might have the structure needed to enter. SMEs managers must use this kind of frameworks before making decisions.

Another side to be evaluated and developed in LCC's SMEs is the technological one. Not only managerial and financial issues are involved, but also very important issues are the development of materials, types of parts, components, capabilities, manufacturing execution, and others related to the technology requirements for specific part production.

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## APPENDIXES

### I. Definitions

- **5 Why:** The 5 why's process refers to the practice of asking five times why a failure has occurred in order to get to the root cause or causes of a problem (the actual number of why's is not as important as arriving at the root cause).
- **8D:** The 8D process (problem awareness, launch team, contain, diagnose, action, verify, prevent, and closure) is a problem solving method for product and process improvement.
- **APQP:** Advanced Product Quality Planning.
- **BAA:** Bilateral Airworthiness Agreements are executive agreements concluded prior to 1996 through an exchange of diplomatic notes between the U.S. Department of State and its foreign counterpart based on FAA technical recommendations.
- **Cause-Effect/Fishbone/Ishikawa/ diagrams:** These diagrams are used in identifying and organizing the possible causes of a problem. The brainstorming focuses on machine, environment, method, human, measurement, and method.
- **CA:** Corrective Action.
- **Certified Supplier:** Supplier who has been authorized to perform production verifications to release their shipments to the customer.
- **CI:** Continuous Improvement.
- **Critical Parts for APQP:** Any part identified as a key characteristic, air worthiness or flight safety, with a history of IDR's and/or escapes, or identified as critical by the customer.
- **Disclosure:** A notification by a supplier or processor of a discrepancy on product which has already shipped to an OEM/Tier 1 or OEM/Tier 1's customer.
- **DSQAR:** Designated Supplier Quality Assurance Representative (certified suppliers only)
- **ECN:** Engineering Change Notice.
- **FAA:** Federal Aviation Administration.
- **FAI:** First Article Inspection.
- **FAIR:** First Article Inspection Report.
- **Flight Safety Parts:** Any part, assembly or installation whose failure, malfunction or absence would cause loss of or serious damage to the aircraft and/or serious injury or death to the occupants.
- **FMEA:** Failure Mode Effect Analysis. FMEA is a risk assessment tool that examines potential product or process failures, evaluates risk priorities, and helps determine counteractive actions to avoid the identified problems.
- **Flowdown:** the process of ensuring that all levels of sub-tier suppliers receive ALL detailed information to properly plan, manufacture, process, and ship product. Includes engineering drawings, specifications and quality requirements.
- **FOD:** Foreign Object Damage.
- **Hardcopies:** paper copies of originals of quality documents.
- **IDR:** Inspection Discrepancy Report (OEM document).
- **ITAR:** International Traffic in Arms Regulations.
- **Key characteristics:** per SAE AS9103 section. 3.1.
- **May:** a clause that contains the verb "may" is strongly recommended (may be waived by written release from the customer).
- **Model:** 3 dimensional electronic representation of a part or assembly created in Catia V5.
- **MRB:** Material Review Board.
- **NADCAP:** National Aerospace and Defense Contractors Accreditation Program.
- **OEM:** Original Equipment Manufacturer

- **PQR:** Customer Product Quality Representative.
- **Probation:** Evaluation period to determine/validate that the corrective actions implemented are in fact affective and providing continuous, consistent positive results.
- **Processor:** Provides processing outside of normal machining operations.
- **Proprietary products:** products designed by the supplier (see section 4.1).
- **RPN:** Risk Priority Number. The RPN process is used to quantify risk and manage the Continuous Improvement process. The numerical part of RPN is a derived quantity or amount that assigns a value or significance to the importance of a particular fault or failure (a large number indicates high risk while a small number signifies low risk). RPN is typically calculated by the formula:  $\text{Frequency} \times \text{Severity} \times \text{Detection}$ .
- **SCAR:** Supplier Corrective Action Request.
- **SEAD:** Stop Escapes at the Door. This is an audit designed to stop discrepant material from shipping to an OEM or its customers by means of detailed product verification checklist.
- **SHALL:** a clause that contains the verb "shall" is a mandatory requirement (will result in a major audit finding if not in place).
- **SNAG Sheet:** Internal discrepancy report (internal to the supplier).
- **SPC:** Statistical Process Control.
- **Standard Hardware:** A part or material that conforms to an established industry or national authority published specification, having all characteristics identified by text description, National/Military Standard Drawing, or catalog item (ref. AS9102A).
- **Supplier:** Provides product which will be part of or support a landing gear (typically airworthy products for aircraft installation).
- **Tag:** Inspection Discrepancy Report (OEM document).

## **II. Mexican Aerospace Industry SWOT Analysis**

### **Strengths**

#### *Geographic location*

- Mexico has 12 Free Trade Agreement with more than 40 countries.
- More and better possibilities of access to the American industry (BASE).
- Reduction of times and costs (North America).

#### *Support programs*

- Support programs on the part of the Federal and State governments.
- Agreements with universities and companies to support the aerospace industry.

#### *Technology and Infrastructure*

- In the aerospace industry: 84 companies dedicated to the manufacture, 13 to maintenance and 12 to the design and engineering.
- Bombardier, Honeywell, GE and other companies have important projects in Mexico.
- Experience in the sectors automotive, electronic, consumer and packaged goods, lighting, and others.
- Manufacture processes in: electronic manufacture of parts and components for turbines, components, plastic cables and harnesses, injection, precision machining, among others.

#### *Quality in processes and services*

- Around 25 companies accredited by NADCAP.
- More than 25 companies with AS9100 registry and others in process to achieve certification.

### **Weaknesses**

#### *Geographic location*

- Little access to the European market (United Kingdom, France and Germany).
- Lack in binational agreements with the United States for the manufacture and parts certification done in Mexico by aerospace industry.

#### *Support programs*

- Inadequate industrial policy and insufficient fiscal incentives.
- Lack of state strategy for the attraction of foreign investment.
- The universities, except for some exceptions (ITESM, IPN) have not implemented training programs dedicated to the aerospace industry.

#### *Technology and Infrastructure*

- Difficulty of the technological reconversion of automotive small and medium sized companies towards the aerospace industry.
- Absence and/or insufficiency of aeronautical specialized services from factories or centers.
- Lack of innovation and technological development in companies.

#### *Others*

- To reinforce the competitiveness approach.
- To count on greater information of Benchmarking.

### **Opportunities**

- Supply needs from Bombardier Aerospace and others OEM/Tires 1, specially structural parts (aluminum, stainless steel, titanium, etc.).
- Airplanes maintenance is an area of opportunity and an interesting market niche.
- Non-Destructive Tests Development.
- Development of aerospace processes centers.
- Joint-ventures in aerospace sector first level with Mexican companies.
- Local supply development in special processes, machining and registered metrology.

## Threats

- Instability in the aerospace industry market.
- Without an affluent development platform structure and the lack of communication, turns the aerospace industry globalization a risk for the region (Mexico).
- The reforms in the strategic sectors of the country have not been developed yet.
- High levels of investment for the aerospace technological development in competing countries.
- Loss of competitiveness and manual labor highly qualified.

## III. Mexican Aerospace Industry Distribution

Last years companies have been installed in México which are related directly with the aerospace industry (Tier 1, Tier 2) regarding to components manufacturing, and which offer interesting although different grades of low cost manufacture according to the Mexican wage rates (see Figure A-1 and A-2).

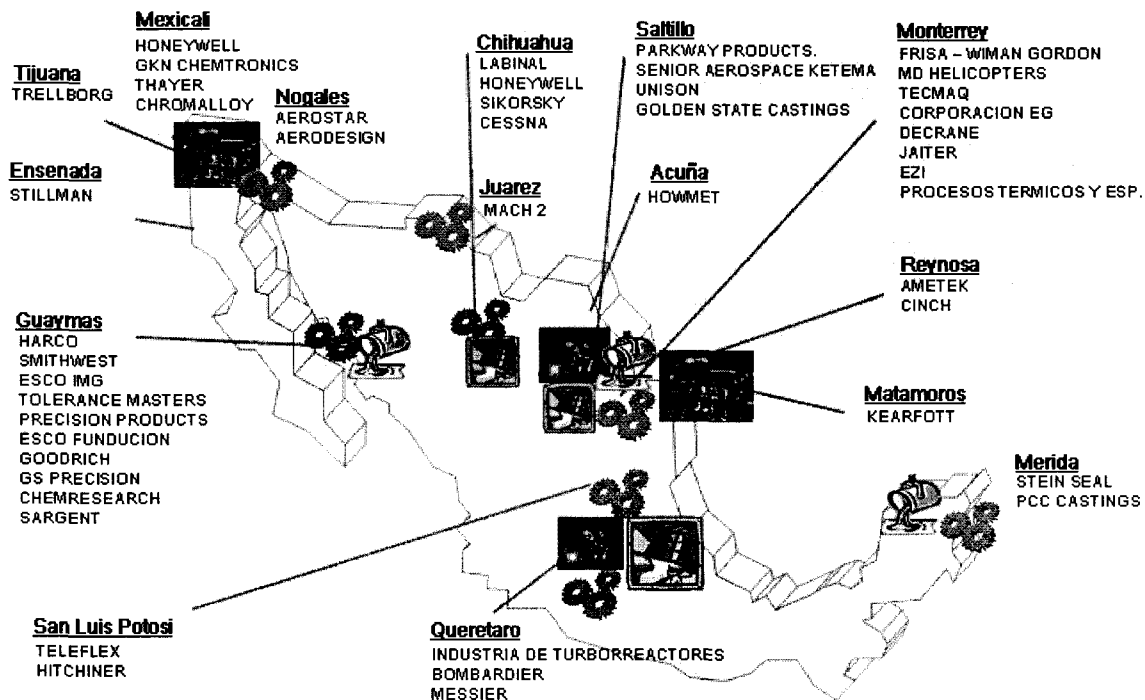


Figure A-1. Geographic distribution of the Tier 1 and tier 2 companies established in México participants in the aerospace industry supply chain, exclusively manufacture enterprises in 2006 (services companies are excluded).



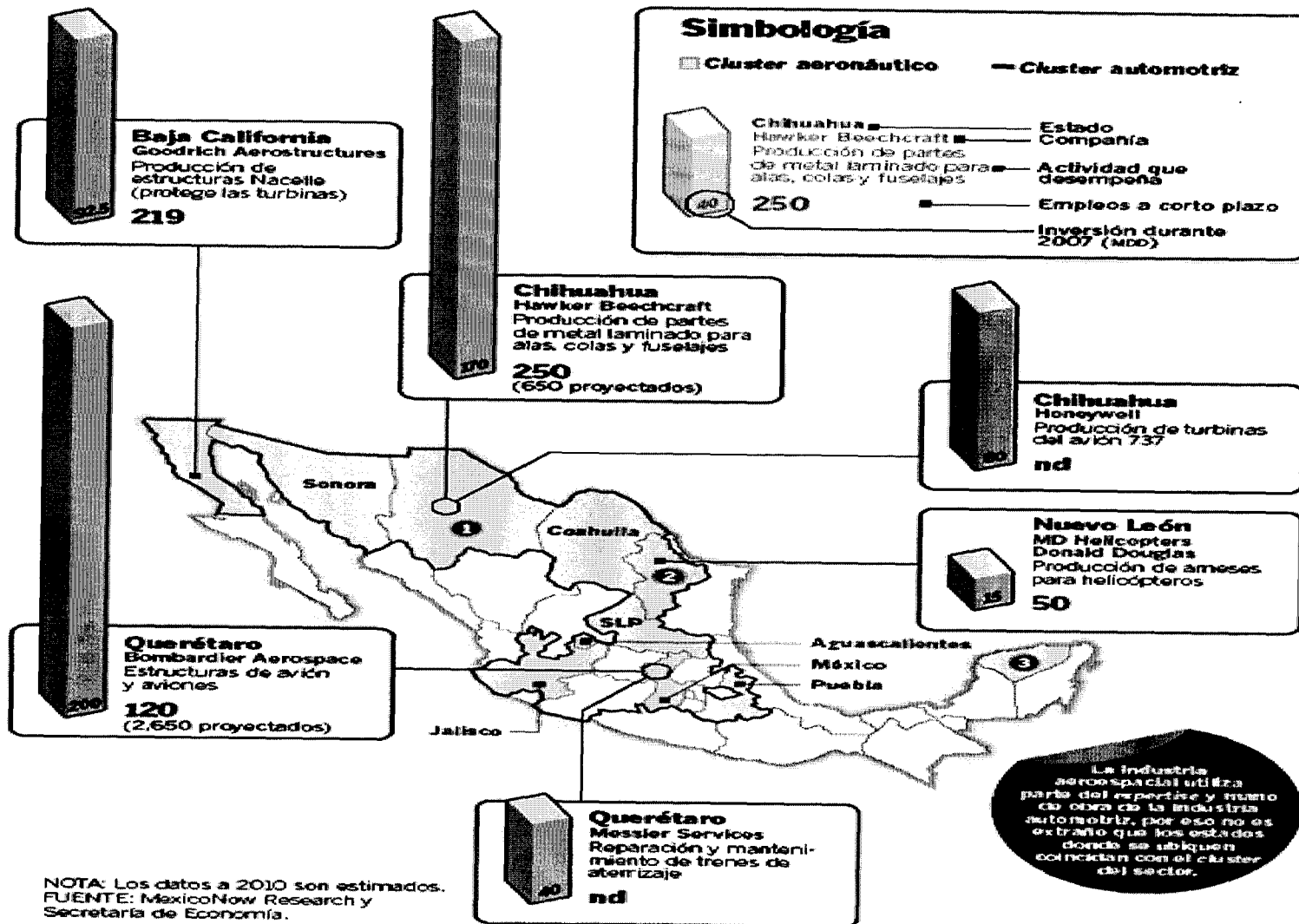


Figure A-2. Aerospace clusters in México, in 2007.

## **IV. Differences Between ISO 9001:2000 and AS9100B (Sedlak, 2006)**

The material contained in this section is for organizations that wish to comply with the requirements of AS9100B.

The focus is limited to the differences (deltas) between ISO 9001:2000 and AS9100B regarding manufacturing, the design requirements are not included in this document since they are outside the reach of the same one. It is assumed that the requirements of ISO 9001:2000 are understood by the reader.

It should be noted that throughout AS9100B, there are requirements that make reference to “contract requirements” and/or “regulatory authorities.” In such cases, it is mandatory to first refer to the contract and, as applicable, regulatory requirements and make a determination of applicability.

Since “notes” are included for guidance, they have not been treated as requirements. This does not in any way diminish their importance.

Each section has three parts:

### **Requirement**

The clause and/or sub-clause number containing the differences is listed, along with a summary of the subject applicable subject matter. For the full text of the requirements, the reader will need to refer to the copyrighted version of AS9100B.

Copies of AS9100B can be obtained from:

SAE World Headquarters. 400 Commonwealth Drive. Warrendale, PA 15096-0001  
USA. Phone: 724-776-4841. [www.store.sae.org](http://www.store.sae.org)

### **Summary**

This is an attempt to emphasize the key points of each clause. In no way should the reader rely on summaries to be all-inclusive. The text of AS9100B is the source document.

### **Comments**

These are suggestions and considerations to be prepared before facing audits, which have been reviewed by different interviewed people from OEM and Tier one’s quality assurance departments. They are in no way meant to be all-inclusive. Each circumstance will have its own unique set of considerations.

### **Requirement**

#### **1. Scope:**

### **Summary**

- ISO 9001:2000 is the basic requirement.
- Additional requirements have been added specific to the aerospace industry.
- Exclusions are limited to the requirements within Clause 7, and such exclusions do not affect the organization’s ability, or responsibility, to provide product or service that meets customer and applicable regulatory requirements.

- Some elements of the QMS may be executed for a site at a remote location, such as a corporate office. Regardless, the functions must be included in the scope of the QMS, with reference to where these remote, support functions are executed.
- All applicable elements of AS9100B must be addressed by the various organizational processes and included in all certification activities.

#### Comments

- All applicable elements and organizational processes must be subjected to assessment both for initial and recertification assessments; sampling of these organizational processes is permitted during on-going surveillance actions.
- All inclusions must be justified by the organization being certified.
- If specific processes are executed at a remote location(s), the effectiveness of the interactions between the various locations will be assessed.

#### Requirement

##### 3.4.2. Product:

#### Summary

- This is a basic definition of product with emphasis on aerospace industry considerations.
- Focus is on the intended product (that which is purchased by the customer).
- By-products affecting the environment are generally excluded (see below).
- Products can be of a hard (washers, engines, propellers) or soft (knowledge, concepts) nature.
- In most cases, the scope of the certification audit will be limited to the quality management system under which the “products” are manufactured.
- The one exception for this is those special cases where the organization has integrated its QMS with its EMS (ISO 14001). In these cases, the by-products of the process may enter into a certification decision. However, it will be under the requirements of ISO 14001, not AS9100, by an EMS auditor.

#### Comments

- The scope statement that will ultimately be stated on the certificate is very important. It must define the products and/or services being supplied by the organization, and the general processes used to produce and deliver them. It must also include reference to any remote, support locations.
- The QMS needs to be very well documented and fully encompass the products and/or services provided by the organization.

#### Requirement

##### 3.3.1, -.5, -.6. Organization:

#### Summary

- The three terms listed above define the macro process flow:
  - Customers provide requirements to organizations
  - Organizations pass down requirements to suppliers.
  - Suppliers provide materials and services to organizations.
  - Organizations provide products to customers.
- These three terms define the relationships that exist in all business organizations. Requirements ultimately start with customers. Organizations supply products, often using services of suppliers.

#### Comments

- For the most part, these “terms” will be audited as part of the overall assessment process, perhaps with emphasis on the purchasing and design processes (if applicable at the site being assessed).

#### Requirement

##### 3. Key characteristics:

#### Summary

- The term “key characteristic” is not unique to aerospace, but it does have a high level of importance. In other industries, the following terms are similar: special characteristics, key product characteristics and critical characteristic.
- This term applies not just to product, but also to material and processes.
- Safety is often a consideration when designating key characteristics.
- It is common for some sort of symbol to be used to highlight or designate key characteristics.
- Key characteristics can be designated by the customer or by the organization.
- As applicable, the existence of key characteristics must be communicated to all applicable personnel, including suppliers. (Refer to configuration management.)
- Key characteristics often have special controls associated with them, e.g. special records, and/or tests, special tools, special training for applicable personnel.

#### Comments

- The key characteristics must be determined, designated, communicated and controlled by the quality and/or engineering documentation(s) of the organization.
- Auditors will review: working documents to see if key characteristics are clearly communicated (as applicable), also records for those key characteristics that have special controls defined, and the performance to verify if they are reviewed at the frequency required.

#### Requirement

##### 4.2.1f. General

- It is no uncommon for customers and/or regulatory agencies to “pass down” requirements to organizations. Whenever this occurs, it is required that the organization develop methods for including such requirements in its documented quality management system.
- There are many specific requirements that could be “passed down.” Some examples are:
  - Requirement for specific non-destructive evaluation.
  - Requirements to use specified suppliers.
  - Special labeling requirements.

#### Comments

- Auditors will examine customer purchase orders, and will look for specific requirements that may be “passed down”. Those requirements must be included within the documented QMS.
- Auditors will assess the effectiveness of the accessibility of documents to those employees that have a need for their use.

#### Requirement

##### 4.2.2b. Quality manual

#### Summary

- Generally, in ISO 9001 system, it is not required to make direct linkage or reference in organization procedures to the clauses of the Standard. However, AS9100B makes this a requirement.

- This requirement is limited to those procedures that are required by the standard as well as those that the organization determines to be necessary.

#### Comments

- The auditors will review how the organization has met this requirement during the document review phase of the assessment and during the assessment of all changes to the QMS.

#### Requirement

##### 4.2.3.g. Control of documents.

#### Summary

- This is a requirement aimed at keeping those that have a need-to-know informed. The purpose is to prevent unintended consequences.

#### Comments

- The organization must maintain a change log or an instrument to control changes to documents, and coordinate those changes with customers and/or regulatory authorities.
  - Customers and/or regulatory bodies need to be notified of such changes. If not, the organization must determinate legitimate justification for the lack of notification.
  - This requirement may apply to customer-supplied documents, e.g., part drawings, and other design requirements.

#### Requirement

##### 4.2.4. Control of records:

#### Summary

- The first added requirement emphasizes “controlling” records that are created or retained by suppliers. Remember, suppliers provide organizations with materials, components, products and services.
  - Records could include traceability documents, certificates of inspection, testing, analysis, and other such documents.
  - There is special emphasis on records that are created and retained by suppliers. This requires the organization to specify or “pass down” requirements to suppliers regarding control of such records. Control may include items like a list of records to be controlled, storage, accessibility, change authorization (or forbidden to make changes), and disposal.
- The second added requirement addresses the need to make records available to customers and regulatory authorities, in accordance with contract or defined in applicable regulations.
  - The access mentioned is only to those specified in the contract or defined in applicable regulations.

#### Comments

- There is a heavy emphasis on creation and control of records in the aerospace industry. The organization must determine what records are required, by a self determination, by the customer in the contract or by applicable regulations.
- The organization must have documented procedures for its controls defined, also must pass down efficiently the requirements to the supplier and to have it controlled.

#### Requirement

##### 4.3. Configuration Management

#### Summary

- Configuration management involves control of all documents that pertain to the product, including such items as part drawings, material specifications, field service manuals, installation instructions, cross-reference documents, part samples, warranty documents, just to name a few.
- A key aspect of configuration management is interchangeability of components.
- Another aspect deals with existing inventory and product in the field.
  - A subcategory of this, as warranted, may be product recall.

#### Comments

- The company must define its process regarding configuration management and the extent of the process must be appropriated to the product.
- The records of changes must emphasize on interchangeability, inventory, field stock (if applicable), and product already in use. It is important that requirements in the configuration management of the organization address drawing notes.

#### Requirement

##### 5.5.2 Management representative:

#### Summary

- In aerospace focused manufacturing, there is a need to have at least one person inside the organization that, in a very real case, has the authority to speak for the customer or regulatory authority. This person must be a management representative (MR) as a minimum.
- Having “organizational freedom” means that this person does not need to seek authority for each action on a case-by case basis. Rather, the MR is authorized to take action that is binding upon the organization – period.

#### Comments

- The authority of the MR must be defined in the quality documentation. If the MR has limitations, these must be legitimate and without conflict with this requirement.
- The auditors will review records of actions, consequences, follow-up, etc., where the MR executed his/her authority, and also the organization chart and reporting relationships is going to be assessed, so there a true organizational freedom.

#### Requirement

##### 7.1.e. Planning of product realization:

#### Summary

- AS9100 does get specific regarding maintenance (whereas ISO does not).
- “Resources” includes: personnel, equipment, repair parts, tooling and/or machine repair and maintenance facilities (may be internal or external).

#### Comments

- The maintenance department personnel must have certain level of competence.
- The auditors will review:
  - inventory of repair parts, tools, etc.,
  - the organization’s maintenance and/or tool repair facilities. If either of these is outsourced, there must be controls to assure that product continues to meet all requirements,
  - the maintenance and/or tool repair records. The organization shall have evidence of post-action conformance of product,
  - that maintenance activities occur as scheduled,
  - if the organization provide the correct resources to avoid bottler necks.

## Requirement

## 7.2.2d. Review of requirements related to the product

## Summary

- In essence, this requirement says: “Don’t just take the order.”
- There is a defined requirement to define the risks, analyze their potential impacts, and take actions to mitigate negative effects.
- Another view: Don’t assume anything. If there is anything that is in question, work with the customer in advance. The goal is prevention of problems.

## Comments

- The organization must have evidence and records of contract review processes/actions, including customer inputs and/or responses.
- The organization, must identify potential risks, take actions, and have a level of customer involvement.

## Requirement

## 7.3.6.2. Design and/or development verification and validation testing:

## Summary

- The emphasis is in control of all aspects of verification and validation testing.
- In a few words: be sure the correct product, at the correct revision level and status, is being tested; the test method is defined and adhered to; results are recorded; test results meet defined requirements.

## Comments

- The organization shall have methods for verification and validation testing to the defined requirements, and all failures documented.

## Requirement

## 7.3.7. Control of design and development changes.

## Summary

- “Changes” are very important to all aspect of aerospace manufacturing.
- It is not uncommon for contracts to have defined requirements for customer and/or regulatory authorities to serve authority for all changes.
- Even if an organization is “design responsible”, there may be contract or regulatory authorities to reserve authority for change approval for themselves.
- Changes may affect the airworthiness of an aircraft. The customer and FAA (or equivalent agency in the country) must be involved.

## Comments

- The organization must be aware of the contract requirements.

## Requirement

## 7.4.1a-e. Purchasing process

## Summary

- It is not uncommon for customers to designate suppliers for certain materials, components, assemblies and services.

- Being “customer-designated” does not relieve the organization of responsibility for controlling the quality from such suppliers.
- All suppliers are to be “approved” via an organization-defined process; this includes a disapproval process and defined authority for all such actions.
- There is special emphasis on out-sourced special processes, such as welding, plating, Non-destructive Evaluation (NDE), etc.
- There may be customer approval required for outsourced work.
- There may be NADCAP approval required for special processes.

#### Comments

- Auditors will review contracts, engineering requirements, part drawings to determine if there is any customer-designated suppliers or requirement for customer approval of suppliers. Also, auditors will review the receiving and in-process inspection records that pertain to these suppliers; check for incoming and in-process conformance.
- The organization must have a defined supplier control process that involves supplier on-site evaluations, records.
- The organization must have appropriate and effective corrective actions issued to suppliers, and supplier performance data.

#### Requirement

##### 7.4.2d-j. Purchasing information

#### Summary

- The overriding theme of this list of requirements is communication of important information, at the current or applicable level, to appropriate parties.
- The details of these requirements are, for the most part, self-explanatory. There is emphasis on communication upstream and downstream in the event of a problem.
- Suppliers are not to change product or manufacturing processes without first informing the organization.
- Right of access to suppliers’ (and, as applicable, to sub-tiers) facilities and applicable records is required; applies to the organization, customers and regulatory authorities.
- If suppliers purchase from lower tiers, they have a responsibility to pass-down applicable requirements and controls.

#### Comments

- The auditors will review the contract and engineering documents to determine what is being purchased and if all these requirements are being met (flow down) in the documented QMS as well as in practice.

#### Requirement

##### 7.4.3.a-e. Verification of purchased product:

#### Summary

- This requirement provides a list of acceptable methods for supplier-provided product by the organization.
- The method must be appropriate and effective.
- Generally don’t use a product until it is approved. Positive recall is permitted, but should not be used unless fully warranted and the process effectively prevents the flow of nonconforming product to the customer.
  - Work that has been subcontracted generally has paperwork associated with its delivery to the organization, e.g. test reports, data packages, etc.



- Test reports need to be periodically validated – typically by the organization or an outside laboratory.
- Delegation is a highly visible process, not to be taken lightly. Those that are granted delegated authority must be competent and be granted authority for unencumbered decision making.
- As warranted by contract, customers and their representative must be able to verify product at suppliers prior to use by the organization. Such verification shall not be used by the organization as evidence of acceptance – that is, the organization retains its own responsibility to verify conformance of purchased product even if the customer has pre-inspected it and found it to be acceptable.

#### Comments

- The organization must have effective defined methods for acceptance of purchased products and to produce records for conformance of purchased product. Its purchasing documents must determine how suppliers are informed of their requirement to permit on-site verification of product by customers.

#### Requirement

7.5.1. Control of production and service provision:

#### Summary

- A control plan lists the methods used at each operation to assure conformance of product (e.g. gages, frequency, records, operations, actions to take if nonconforming product is identified); required for key characteristics.
- If product transformation actions make inspection impossible, upstream controls are required.
- There is a requirement for utilization of variable measurements to be taken; minimize the use of attribute gages, e.g., go/no-go gages.
- Special processes (e.g. welding, plating, painting) require special controls.

#### Comments

- Auditors will assess the effectiveness of in-process control methods, with a special emphasis on key characteristics and special processes, in order to prevent the production of (or at least the flow of) nonconforming product.

#### Requirement

7.5.1g-k. Control of production and service provision.

#### Summary

- This requirement addresses the need to account for all material – from start to finish – to preclude the occurrence of nonconforming product being shipped to the customer.
- Consideration given to split lots – duplication of applicable paperwork, configuration control, especially of non-used product is placed back into inventory.
- The prevention of damage from the presence of foreign objects is of high importance in aerospace work. (FOD = foreign object damage.) Foreign objects are any objects that do not belong in/with the defined product. Typically, this may include items like dirt, chips, wrong or mixed parts.
- A criterion for workmanship means communicating how to determine good from nonconforming. If representative samples are used, they need to be controlled in a manner similar to gages.

#### Comments

- The organization must have effectiveness and control to account for all material, special emphasis on split lots, reworked and repaired product (done in accordance with approved procedures), take care for the presence of foreign objects.

- If the organization has split lots, all processing executed after the split must be documented.

#### Requirement

##### 7.5.1.1. Production documentation:

#### Summary

- Product operation shall be executed in such a manner that all personnel have available to them correct and current data.
- Part of this control includes the listing of required tooling and, as applicable, numerical control information.

#### Comments

- The organization shall have sufficient documentation that accompanies product through the manufacturing processes, to assure conforming product at all phases of manufacturing.
- Numeric Controls (NC) in place must be controlled to the extent necessary to assure content, conforming product.
- The NC program must be used on all parts in the lot, and if not, there must be a review of this action and acceptable results.

#### Requirement

##### 7.5.1.2. Control of production process changes:

#### Summary

- “Changes” require proper control, similar to design changes.
- All changes must be documented.
- It is not uncommon for customers to require their approval of any process change.
- If a process is changed, the effect on the resultant product must be evaluated to validate continued conformance.
  - This may include changes to NC programs.

#### Comments

- Customers must have defined “process changes” in the organization (involvement is required).
- The organization must record process changes, with emphasis on validation records for resultant product.

#### Requirement

##### 7.5.1.3. Control of production equipment, tools and numerical control (NC) machine programs.

#### Summary

- Tooling needs to be validated prior to production.
- One common method is termed “first article” inspection. There are others.
- Tooling needs to be maintained, during use and in storage.
- Tooling needs to be inspected periodically on accordance with documented procedures.

#### Comments

- The organization must store records for new and/or rebuilt/refurbished tooling.
- The records must demonstrate effective validation, that is, capability of producing conforming product on a continuing basis.
- The tooling must be stored and effectively protected, and constantly updated to meet current design revision levels. Changes to NC programs require a new first-article.

#### Requirement

#### 7.5.1.4. Control of work transferred on a temporary basis, outside the organization's facilities:

##### Summary

- On occasion, organizations may find it necessary to outsource one or more of its standard manufacturing processes. (This is different from purchased product.)
- If this occurs, the organization must develop/define effective controls to assure that only conforming product reaches the customer.

##### Comments

- When outsourcing, the organization must qualify the source, put controls in place to assure that only conforming products reaches the customer, paying particular attention to the required paperwork, e.g. routers, inspection sheets, first-article documents, it must be flowing to the outsourced organization and come back with the product as required.

##### Requirement

#### 7.5.1.5. Control of service operations:

##### Summary

- Service typically occurs after delivery. It differs from warranty work.
- Since service activities have the potential to affect product quality, they are expected to have equal, and sometimes more, control than the original manufacturing processes.
- Servicing often involves working with multiple revision levels – read, configuration control.

##### Comments

- The organization could have contractual requirements for post-delivery service. If yes, the organization must assure conformance at the required product revision level, with a good competency of its service personnel, good calibration of tools and/or gages used in service applications. The organization must record services to review and use this information.

##### Requirement

#### 7.5.2a & c. Validation of processes for production and services provision:

##### Summary

- Special processes are those, the result of, that cannot be inspected without destroying or damaging the part. For example, welding, soldering, brazing, heat treatment, plating, some aspects of painting, etc. all of these require destructive testing to assure testing.
  - Welding requires the weld to be pulled to destruction or cut and micro-analyzed for integrity.
  - Heat treated parts require some sort of Rockwell-type test or a micro-analysis.
  - Plating requires micro-analysis and possibly corrosive environment testing.
  - Painting, to test for adhesion, may require scoring with a razor blade and tape application/removal.
- In these cases, the control must be on process parameters, including process controls, training of personnel, special records.
- AS9100B requires that all such special processes be qualified and approved prior to use (for production). This may require NADCAP certification.

##### Comments

- If the organization is doing special processes in its manufacture processes or outsourced, there must be records of:
  - Qualification of the process(es)
  - Qualification of the personnel

- Process and/or product tests.
- Is the organization outsourcing special processes, it must have records for qualification of the supplier, control imposed by the organization, inspection records, corroboration testing as applicable, NADCAP.
- If changes are made to the process, subsequent process and product re-qualification must meet all applicable contract requirements.

#### Requirement

7.5.3& a-d. Identification and traceability.

#### Summary

- It is not uncommon for a customer to purchase similar products at different configuration levels. When this occurs, it is incumbent upon the organization to maintain separation and control of the differing configuration levels.
- Use of stamps, etc., to indicate acceptance of processes or products is common in the aerospace industry. Such media needs to be controlled to preclude misapplication misuse, including use by unauthorized personnel.
- As applicable, traceability is very important. The primary purpose is to minimize the size of a recall should such action become necessary. In the absence of traceability, all product purchased becomes suspect.
- Items a-d spell out specific requirements, and are self-explanatory.

#### Comments

- In the contract, configuration levels must be ordered, and a level of traceability would be required.
- The organization must have records of shipped product and in-process for conformance to traceability requirements. The records of all components and manufacturing processes must have conformance with shipped product.

#### Requirement

7.5.5a-f. Preservation of product.

#### Summary

- These requirements address the critical need to maintain the integrity of product after manufacture through all phases of the delivery process.
- There is special emphasis on the prevention, detection and removal of foreign objects.
- Shelf life has to do with expiration dates of product or material. If applicable, these shall be clearly marked and adhered to. FIFO (first-in, first-out) is one way to minimize problems with shelf life.
- Hazardous materials typically require special marking, packing, and packaging. They may also require special transportation modes.

#### Comments

- If special, post-manufacturing requirements associated with identification, packing and packaging are in the contract, there must be conformance to these requirements. However, if there are no special requirements, the organization must ship and receive the product as intended. Shipping documents must be identified and protected.

#### Requirement

7.6 & f. Control of monitoring and measuring devices:

### Summary

- AS9100B gets very specific regarding the nature of instruction documentation required for a compliant gage calibration system.
- Gages need to be listed, identified, located, have a defined frequency for calibration, defined check method and acceptance criteria.
- Additionally, the process for recalling gages (getting them into the calibration function) needs to be defined.

### Comments

- The organization must have documented procedures and work instructions, as applicable, for gage calibration, with adequacy of the environmental conditions.

### Requirement

#### 8.2.2. Internal audit.

### Summary

- The internal audit process is “looking at the trees”, that is, it is the process whereby the details of the organization’s processes are assessed.
- AS9100B has a requirement to take a disciplined approach to internal audits; reliance on check sheets and similar tools. This assumes an effective planning process.
- The organization is free to select and implement its own tools and approach to internal audits.
- The internal audit process will be deemed effective if it discovers weakness prior to any negative effect on product. The internal audit is a powerful prevention tool.
- As has been seen throughout AS9100B, there is the admonition to pay strict attention to contract and/or regulatory requirements – if applicable.

### Comments

- Internal auditing procedure must be documented (tools used by auditors: checksheets, process flow diagrams, etc.).

### Requirement

#### 8.2.3a-c. Monitoring and measurement processes:

### Summary

- The focus here is on process nonconformity.
- Think of it this way: A design process could have a latent error; purchasing may have issued a purchase order to the wrong design level; production scheduling may have issued manufacturing documents that contain errors, etc; etc. Any of these may result in product nonconformities, but the cause was a nonconforming process.
- Processes found to be nonconforming must be corrected.
- When a nonconforming process is identified, the possibility/probability of the nonconformity resulting in product nonconformity must be assessed. Actions may include: design review, dimensional inspection, visual analysis, laboratory analysis, inventory review or product recall (worst case), just to name a few.
- If nonconforming product is identified, it must be identified and controlled in accordance with the organization procedures and the requirements of clause 8.3. The customer may need to be notified, especially if they are design responsible and in charge of the airworthiness certificate.

### Comments

- Process failures can be detected in a variety of ways, including internal audits, in-process inspection, analysis of returned product, customer complaints. The organization must have records of all these inputs about the action taken to prevent recurrence of the problem.

#### Requirement

##### 8.2.4. Monitoring and measurement of product.

#### Summary

- There is emphasis on key characteristics; this does not preclude monitoring and control of other, non-key characteristics.
- Sampling plans shall have statistical validity. The acceptance number shall always be “zero.”
- Inspection activities need to be completed as planned. In those cases where such inspection must be delayed, processing through subsequent process may proceed provided it is done such that positive-recall must be assured; this does not include shipping to the customer unless previous approvals are obtained on case-by case basis.

#### Comments

- The organization must have control processes for adequacy and effectiveness of the key characteristics defined, also a procedure for positive recall of in-process product control, and controls to assure that no nonconforming product reaches the customer.

#### Requirement

##### 8.2.4.1a-d+. Inspection documentation:

#### Summary

- Required inspection actions must be documented. It may be done on separate inspection instructions, or it may be incorporated in to the production documentation, e.g. routers, travelers, etc.
- Such instructions must define criteria for acceptance or rejection. For dimensional characteristics, this is the nominal value and the associated tolerance. For visual characteristics, there should be approved (controlled) visual standards. For performance characteristics, there should be defined conditions and results.
- Instructions must define where and when inspections take place.
- Inspection results must be controlled, and include a-d above.
- Gages, etc., shall be defined, and, as required, special instructions for application and use.

#### Requirement

##### 8.2.4.2. First article inspection (FAI):

#### Summary

- New parts require a first article inspection.
- Depending upon the nature of the part, this may be as simple as a dimensional inspection (full 100% layout) or as complex as to include chemical analysis, performance testing, or other related tests. (AS9102 may be a requirement).
- If there are subsequent changes, the FAI needs to be repeated. Typical “changes” include engineering changes, significant manufacturing process changes, and new suppliers.

#### Requirement

##### 8.3. Control of nonconforming product:

#### Summary

- Nonconforming product, by its very nature, requires a lot of attention and control.
- The organization must define its process for reviewing and dispositioning such product.
- This is typically done via use of a Material Review Board, typically consisting of engineering, quality and customer-representative personnel. (Others may be included.)
- Personnel participating in such actions must have qualification and competency for the actions they take.
- "Use-as-is" or "repair" are not acceptable disposition categories – unless prior approval is received from the customer.
- There are some exceptions to this. For instance, a stamped part may be rejected for excessive burrs. Such parts can typically be "repaired" by some non-standard de-burring operation. Such actions are acceptable provided the resulting product does not deviate from contract requirements.

#### Requirement

8.3 (cont'd.) Control of nonconforming product:

#### Summary

- Scrap control is very important to AS9100B certification. The intent is to preclude inadvertent use by the organization or by unscrupulous scrap handlers. In other words, there must be absolute assurance that scrap parts never find their way in to the aircraft.
- Scrap must be identified in conspicuous and permanent manners, followed by actions to make it absolutely unusable.
- Should an organization inadvertently ship nonconforming product, it has a responsibility to notify all applicable customers. Timely is not specifically defined, but is usually interpreted as hours not days.
- Such notification requires conveyance of all required descriptive information.

#### Comments

- The organization must have a procedure for scrap control and its records. Scrap must be handled, marked and ultimately rendered unusable.

#### Requirement

8.5.2g & h. Corrective action:

#### Summary

- A documented procedure is required for corrective action.
- This procedure must contain specific actions and controls for those situations where it has been determined that suppliers are the source of the root cause of the nonconformance.
- There must be defined actions that address subsequent actions where the actions originally planned are not completed on time or are not effective.

## ***V. Sourcing Questionnaire for the OEM/Tier One.***

### **1. How do you identify a need for a supplier?**

1. 1. And/or what are your actual supply needs for the México plant in structural parts?  
Could I see in more detail the opportunity areas for Mexican suppliers?

**2. Once you identify the need, how do you identify your sources?**

2. 1. 1. Which of these sources (or what other criteria) do you use to identify potential suppliers?

**3. What do you look for in those sources (skills, capabilities), in terms of:**

o **3. 1. Processes**

▪ 3. 1. 1. Purchasing/Procurement (contracts, etc)

3. 1. 1. 1. In the purchasing process, how is product information conveyed to the supplier?

3. 1. 1. 2. In the verification of the purchased product, do you establish and implement processes to ensure that the purchased products meet the requirements?, not only for your purchases, but also your supplier's purchases?

Types of relationships, that Bombardier Aerospace has with SMEs (small and medium enterprises):

| <del>Buy The Market</del>                                                                                                                                                                                                   | Ongoing Relationship                                                                                                                                                                               | Partnership                                                                                                                                                                           | Strategic Alliance                                                                                                                                                                                                   | Backward Integration                                                                                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>• Arm's length</li> <li>• Clear specifications</li> <li>• Computerized interaction</li> <li>• Significant Business with competitors</li> </ul> <p>Too low.<br/>Very standardized</p> | <ul style="list-style-type: none"> <li>• Medium-term contracts</li> <li>• Some sharing of information</li> <li>• Some business with competitors</li> <li>• Good management relationship</li> </ul> | <ul style="list-style-type: none"> <li>• Longer-term contracts</li> <li>• Extensive sharing of information</li> <li>• Increased trust</li> <li>• Business with competitors</li> </ul> | <ul style="list-style-type: none"> <li>• Long-term relationship</li> <li>• Full sharing of information and plans</li> <li>• Extensive trust and merging of cultures.</li> <li>• Business with competitors</li> </ul> | <ul style="list-style-type: none"> <li>• Ownership of the supplier</li> <li>• Full sharing of information and plans</li> <li>• One culture</li> </ul> |
| <p>Characteristics of different types of supplier relationships. Pyke and Johnson (2007).</p>                                                                                                                               |                                                                                                                                                                                                    |                                                                                                                                                                                       |                                                                                                                                                                                                                      |                                                                                                                                                       |

▪ 3. 1. 2. Manufacturing

▪ 3. 1. 3. Quality

3. 1. 3. 0. Which of these categories (or others) do you include on your supplier evaluation instruments? (For existing and new suppliers).

3. 1. 3. 1. How do you verify the adoption of design requirements down to the lowest level of manufacturing in addition to how your supplier applies the process?

3. 1. 3. 8. Do you design key characteristic (key product, key material, processes or critical characteristics) to your suppliers?

*Key characteristics: For safety considerations. Commonly used by symbols, designated by the customer (organization). Have some special controls associated with them, e.g., special records and/or tests, special tools, special training for applicable personnel.*

3. 1. 3. 10. Do you have Manager Representatives (MR) at supplier's plant or facilities?, If yes, how is their authority defined?, are there any limitations on the authority of the MR?

*In aerospace focused manufacturing, there is a need to have at least one person inside the organization that, in a very real case, has the authority to speak for the customer or regulatory authority. This person must be the management representative (MR) - as a minimum.*



- 3. 1. 4. Human Resources (HR)

- **3. 2. Infrastructure**

- 3. 2. 1. Equipment

3. 2. 1. 1. Do you have certain standard equipment capabilities as a minimum requirement for suppliers?

- 3. 2. 3. Space

3. 2. 3. 1. Do you verify the space capability of a supplier, In terms of its production lines, cells or workshops?

- 3. 2. 4. Tooling

- **3. 3. Technology**

- 3. 3. 1. Information Systems

3. 3. 1. 1. Do you have some engineering and IT capability requirements for suppliers, for example: in terms of CAD (CATIA desirable), MRP, PDM, etc?

#### **4. Once you have potential suppliers, what is the evaluation process?**

#### **5. What are the implications for the supplier (contract/agreements)?**

6. 1. What is the Business process followed to get a contract (documents used)?  
Could I see in more detail this process?

6. 2. What concerns to Bombardier about a Low Cost Country LCC outsourcing, specifically a Mexican SME (by priority)?:

- “**aftermarket**” spare parts maintenance, is it a critical part?
- delivery of LCC parts
- Managing global supply chain
- intellectual property (IP),
- effect on the industry workforce and community,
- new product introduction,
- management time and expertise,
- impact on sales growth,
- and customer/market concentration,

## ***VI. Quality Questionnaire for the OEM/Tier One.***

### **1. What do you look for in those sources (skills, capabilities), in terms of:**

- **1. 1. Processes**

- 1. 1. 1. Quality

- 
1. 1. 1. 1. Do you apply any supplier evaluation instrument? (For new suppliers).
1. 1. 1. 2. How do you assure an effective communication with the last sub-tier suppliers, how do you assure that requirements are followed at the different supply chain levels, especially for critical processes?
1. 1. 1. 3. Do you have some supply chain control to eliminate nonconformance?, What about inspection, verification techniques, and knowledge at the supplier?
1. 1. 1. 4. If you have some supplier product problems, how do you contain it rapidly and resolve issues robustly? Do you have some process for these kinds of situations?
1. 1. 1. 5. Do you have any monitoring system? If so, what is it?
1. 1. 1. 6. Do you have any enforcement system? If so, what is it?
- 1. 1. 2. Human Resources (HR)
1. 1. 2. 1. How do you measure the capability of the supplier's people?  
E.g.: Specialized soldering people.
- **1. 2. Infrastructure**
    - 1. 2. 1. Equipment
    - 1. 3. 1. 1. Do you verify that suppliers have certain equipment for certain processes?
      - 1. 2. 2. Certifications
1. 2. 2. 1. Do you have an audit process for new suppliers (having AS9100B)? In what consist it?
1. 2. 2. 2. What are the principal benefits, do you think your suppliers get with the AS9100B certification.  
E.g.:
- Access to new markets.
  - Operative improvements and cost reduction opportunities in auditions (less number and resources),
  - Better operation, better quality, reduction in waste and an approach in customer satisfaction.
  - Improved product reliability
  - Better process control and flow
  - Better documentation of processes,
  - Greater employee quality awareness
  - Reductions in product scrap, rewords and rejections
  - Higher auditory and supervision efficiency.
1. 2. 2. 3. What corrective actions do you take with its suppliers whenever defects occur?
1. 2. 2. 4. Do you have defects rate allowed?
- 1. 2. 3. Tooling

1. 2. 3. 1. Do you have any tooling capability requirements for some special parts production?. Or how do you verify tooling specifications?

- **1. 3. Technology**
  - 1. 3. 1. Information Systems

1. 3. 1. 1. Do you have some engineering and IT (Information Technologies) capability requirements for suppliers, in terms of quality systems?

## **2. Once you have potential suppliers, what is the evaluation process?**

2. 1. Do you have a supplier evaluation process? If yes, could you talk me about the process you follow to qualify a new supplier?

2. 2. Do you perform a detailed supplier evaluation through supplier visits?

2. 3. And are these the requirements you ask to candidate suppliers? What else?

- i. Supplier performance areas:
  - Overall personnel capabilities
  - Total quality performance, systems and philosophy
  - Environmental regulation compliance
  - Engineering capabilities
  - Engineering capacity
  - Manufacturing capacity
  - Operational performance: production scheduling and control systems, including supplier delivery performance
  - Compatibility with strategy for product
  - Offset requirement
  - Canadian or other specific content requirement
- ii. Management capability
- iii. Personnel capabilities
  - Employees supporting and committing: quality, continuous improvement.
  - Skills and abilities of the workforce (education and training)
  - Employee morale, workforce turnover, opportunity and willingness of employees to improving a supplier's operation.
- iv. Cost structure
- v. Total quality performance, systems, and philosophy (ISO-AS9100, Nadcap, etc.)
- vi. Process and technological capability
- vii. Environmental regulation compliance
- viii. Financial capability and stability
- ix. Production scheduling and control systems, (MRP-material requirements planning, ERP-enterprise resource planning, etc.)
- x. E-business capability (*see section 3. 3. 1. 1. on this questionnaire*)
- xi. Supplier sourcing strategies, policies and maturity

- xii. Longer term relationship potential
- xiii. Initial supplier evaluation and selection survey.

2. 2. What is the process you follow in order to qualify a supplier?, I understand that: Bombardier has a process for approving a new supplier,

- Assessment,
- Evaluations,
- Quality requirements,
- GAP analysis,
- Suggestions on which the supplier must improve.

**3. Do you have any supplier performance measurement system?, if yes, in what consists it?**

3. 1. Does it provide documentation of actual supplier performance?

**4. In summary, what is the main decision criterion to choose (qualify) a supplier?**

## ***VII. Questionnaire for Aerospace Metalworking Suppliers.***

**1. How do you identify a market opportunity with an aerospace customer (OEM/Tier 1)?**

1. 1. How many contracts do you usually have? For how many aerospace costumers do you usually do jobs at the same time, given the low volume in this industry?

**2. During a supplier evaluation process form Bombardier or other OEM, what do you think they look for in sources (skills, capabilities), in terms of:**

### **2. 1. Processes**

- 2. 1. 1. Purchasing/Procurement (contracts, etc)

2. 1. 1. 1. In the purchasing process, how is product information conveyed to you (supplier)?

2. 1. 1. 2. In the verification of the purchased product, do you establish and implement processes to ensure that the purchased products meet the requirements?

- 2. 1. 2. Manufacturing

2. 1. 2. 1. For Structural Parts, principally aluminum and steel (stainless), what are your main process capabilities? (Look at the web-page [www.noranco.com](http://www.noranco.com) as well).

- 2. 1. 3. Quality

2. 1. 3. 1. How do you assure the adoption of design requirements from the OEM down to your lowest level of manufacturing?

2. 1. 3. 2. How do you assure an effective communication with the last sub-tier suppliers, making sure that the requirements are followed at the different supply chain levels, especially in your critical processes?

2. 1. 3. 3. Do you have some supply chain control process to eliminate nonconformance?

2. 1. 3. 4. Do you receive inspection from the OEM?

2. 1. 3. 5. Do you have Manager Representatives (MR) from an OEM at your plant or facilities?, If yes, how is their authority defined?, are there any limitations on the authority of the MR?

- 2. 1. 4. Human Resources (HR)

2. 1. 4. 1. How has been measured the capability of your employees? For example, specialized soldering people.

- 2. 1. 5. Inventory, Logistics (supply chain)

2. 1. 5. 1. When do you trigger inventory orders?

2. 1. 5. 2. How many do you order at time?

2. 1. 5. 3. How often do you review inventory status?

2. 1. 5. 4. What service targets do you set?

2. 1. 5. 5. Do you use inventory management software?

2. 1. 5. 6. How are forecasting decisions made?

2. 1. 5. 7. In which modality do you work: make to stock or make to order? What challenges represents in terms of delivery times, purchase power, etc.?

## **2. 2. Infrastructure**

- 2. 2. 1. Equipment

2. 2. 1. 2. Have your company been verified about having certain equipment for processes?

- 2. 2. 2. Certifications

2. 2. 2. 1. Having AS9100B and Nadcap certifications, how easy have been the audit processes with OEMs? Is there a reduction in process audits?

2. 2. 2. 2. Are these benefits of AS9100B certification?

- Access to new markets
- Operative improvements and cost reduction opportunities in auditions (less number and resources),
- Better operation, better quality, reduction in waste and an approach in customer satisfaction.
- Improved product reliability
- Better process control and flow
- Better documentation of processes,
- Greater employee quality awareness
- Reductions in product scrap, rewords and rejections
- Higher auditory and supervision efficiency.

Do you have defects rate allowed by your customers?

**AS-9100**

2. 2. 2. 3. What of these problems are more common and what is what you must first take care of?

- Failure to:
  - meet delivery date
  - meet specifications
  - meet the customer need
  - service (in case of giving service)
  - Nonconformance products

2. 2. 2. 4. What of these factors or other factors commonly contribute to your quality problems?

- Tasks were not assigned to the proper individuals
- The individuals doing the work did not get the appropriate information
- Appropriate resources were not available
- Individuals failed to do the work

2. 2. 2. 5. According to your quality management system, what should be identified as a key in aerospace industry and/or what has been the most difficult goal to achieve? I list three main categories:

- **Personnel** - skilled, motivated, and with a clear understanding of what to do and how to do it
- **Processes** - all activities that affect quality must be properly planned, controlled, evaluated, and improved when possible to achieve the requirements
- **System** - defined and documented policies, objectives, organizational structure, resources, responsibilities and processes.

**Production and Service Provision**

2. 2. 2. 6. Do you have some special process(es) for your production documentation?

2. 2. 2. 7. Do you have any...?

- Control of Product Process Changes
- Control of Production Equipment
- Control of Work Transferred Temporarily
- Control of Service Operations

2. 2. 2. 8. Have you done a validation of processes for production & service: when you have to validate the process if it cannot check the product?

2. 2. 2. 9. About identification and traceability: how do you identify the product, its inspection and test status?

2. 2. 2. 10. About customer property: how do you identify, verify and protect the customer property?

2. 2. 2. 11. About the preservation of product: how do you define the processes for stating how to handle, store, package, and protect the product?

**Monitoring and Measurement:**

2. 2. 2. 12. Do you assure the customer satisfaction?, e.g. by asking customers what they think about your products.

2. 2. 2. 13. Do you have some of these processes inside your company?

- Internal Audits
- Monitoring and Measurement of Processes
- Monitoring and Measurement of Product by
  - Inspection Documentation
  - First Article Inspection

2. 2. 2. 14. Do you have a Control of Non-Conforming Product system for the prevention of the use or delivery of nonconforming products?

2. 2. 2. 15. Do you do internal audits? If yes, do you perform these actions in the internal audit process? And/or what else?

- Validate the internal AS9100 quality standards
- Verify Performance
- Identify existing or potential problems
- Report findings to management
  - Both positive and negative (not finger pointing)
- Verify and report the effectiveness of corrective actions.

2. 2. 2. 16. Having AS9100, what could you tell me about the process you have followed in order to get the certification, or what was the most critical point on this process to finally achieve the certification?

1. Get Management's Authorization and Commitment
2. Set-up the AS9100B Implementation Team
3. Write Procedures and Quality Manual
4. Train the Employee
5. Conduct Internal Audits
6. Finalize Corrective Actions
7. Conduct the Registration Audit (External Audit)
8. Complete the Registration Audit Report
9. Finalize Corrective actions and Obtain Registration

- 2. 2. 3. Space

2. 2. 3. 1. Have you been verified for any space capability, In terms of its production lines, cells or workshops?

- 2. 2. 4. Tooling

2. 2. 4. 1. Have you faced any general capability requirements for some special parts production?, something different or that you think has been important.

## **2. 3. Technology**

- 2. 3. 1. Information Systems

2. 3. 1. 1. What are your Information Technologies capabilities basically required as a supplier by an OEM/Tier 1? For example: in terms of CAD (CATIA desirable), ERP, PDM, etc?

- 
2. 3. 1. 2. What organizational communication tools do you think is basic to have, and have you been assessed for these requirements?
- 3. When your performance has been evaluated by a customer (OEM, Tier1)? What do you think are the most performance factors evaluated?**
- 4. What do you think is the most critical part in a supplier evaluation process from Bombardier or other OEM/Tier 1?**
- 5. What are the implications (contract/agreements) for the supplier in the relation supplier-customer (OEM, Tier 1)?**
5. 1. In the business process followed to get a contract (documents used), what do you think is an important difference compared with others industries such as the automotive one?
5. 2. Do you work with "aftermarket" spare parts?, do you do maintenance for these kind of parts? Is it a critical part in your business?
- 6. In summary, what do you think is the main decision criterion by an OEM/Tier 1 to choose you as a supplier?**
- 7. Have you been helped for an OEM/Supplier in your development as a supplier? E.g. by informal technology and purchasing communication, or by formal processes such as:**
- 7. 1. Engineering driven activities:**
    - New Product Development.
  - 7. 2 Procurement-driven activities:**
    - Order Processing
  - 7. 3 Supplier development-driven activities:**
    - Quality, cost, delivery improvement.
    - Transfer of management practice
    - Transfer of technology best practice
    - Transfer of technology lookahead
- 8. When have you had the most critical problems while being an aerospace supplier?, can you talk about these important issue(s)?**

### **VIII. Self-Assessment Tool.**



**Quality***Quality system*

Do your manufacturing facilities have certified Quality Systems?

Do you have a Quality Manager?

Is your company ISO certified? If yes, please list all ISO certifications.

Is your company AS 9100 certified?,

*General (AS9100B-4.2.1f.)*

Does your organization have a method for including customer requirements in your documented QMS?

*Quality manual (AS9100B-4.2.2b.)*

Does your organization make direct linkage or reference in organization procedures to the clauses of the quality Standard? (AS9100 requirement)

*Processors*

Would your organization be able to begin a process in order to complete the Nadcap certification for its special processes?

*Right of access to facilities, personnel and records*

Would your organization be able to have product/process review and validation evaluations or investigations?

*Control of documents (AS9100B-4.2.3.g.)*

Does your organization maintain a change log or an instrument to control changes to documents, and coordinate those changes with customers and/or regulatory authorities?

*Control of records (AS9100B-4.2.4.)*

Does your organization control records that are created or retained by suppliers?

Does your organization "pass down" requirements to suppliers regarding control of such records?

Can your organization make records available to customers and regulatory authorities, according to contracts or defined in applicable regulations?

*Configuration Management (AS9100B-4.3.)*

Does your company practice "configuration management", which involves control of all documents that pertain to the product?

**Process control**

Does your organization document records of manufacturing and inspection of products?

*Monitoring and measurement processes (AS9100B-8.2.3a-c.)*

Is your company able to monitor, measure, and correct nonconforming processes?

**Inspection and testing**

*Product Inspection Status and Certification*

Does your company verify the quality of all products purchased?

*Monitoring and measurement of product (AS9100B-8.2.4.)*

Does your organization monitor and control product characteristics (especially the defined, "key" ones) with sampling plans, statistical validity and an acceptance number of "zero"?

*Inspection documentation (AS9100B-8.2.4.1a-d+.)*

Does your company practice inspection operations, with its instructions and criteria, and document them?

*First article inspection (FAI) (AS9100B-8.2.4.2.)*

Does your company practice First Article Inspection (FAI) on the first piece of a new or delta production run?

*Material Certification requirements*

Would your company be able to use materials (e.g., with laboratory certifications) accompanied by a certificate of conformance?

*Sub-Supplier control*

Does your organization have supplier control to evaluate delivery times and quality?

*Design and/or development verification and validation testing (AS9100B-7.3.6.2.)*

Does your organization control all aspects of verification and validation testing? This means being sure that you use the correct product, at the correct revision level and status, perform a defined test method, and record the results.

Does your company produce records about its verification and validation testing controls?

**Nonconforming product**

Does your organization have a process for identification of non-conforming product?

*Customer Returns*

Does your organization have a process to document all items returned by customers?

*SC control Vs non-conformance*

Does your company have a quality clinic (laboratory) to eliminate potential failures in the process, and a process for corrective failures in a space inside the plant?

*Control of nonconforming product (AS9100B-8.3.)*

Has your organization defined a control, process for reviewing and dispositioning nonconforming product?

Does your organization have a defined process to identify scrap and make it absolutely unusable?

**Corrective / Preventive action**

*Corrective action (AS9100B-8.5.2g & h.)*

Does your company have a documented procedure for corrective actions and controls in-house, and even when suppliers are the root cause of the non-conformance?

*Disclosures*

Would your organization be able to provide a root cause and corrective action plan when a disclosure?

**Continuous Improvement**

*CI Requirements*

Does your organization have an internal continuous improvement program?,

- Lean Manufacturing
- Six Sigma
- Total Quality Management / Total Productive Maintenance
- APQP (Advanced Product Quality Planning) methodology.

**Procurement**

**Contract Review**

*Procurement process*

Would your company be able to have long-term relationship (because of the airplanes' long life) with customers?

*Control of design and development changes (AS9100B-7.3.7.)*

Does your organization have a defined system to adhere to the customer and/or regulatory authorities' design and development changes?

Does your company have documented procedures to notify your customer before making material or process changes?

*Advanced Product Quality Planning (APQP)/Control Plan*

Does your organization have a pre-planning method for new parts?

**Manufacturing Plans**

Does your organization record the manufacturing planning of each individual component?

*Failure Mode Effect Analysis (FMEA) method*

Does your organization have a method to identify potential failure modes for each critical part and its processes, such as FMEA?

*Offload/transfer of work*

Does your organization ensure the capability of all offload sub-tiers and the quality of all products?

*Flowdown*

Does your organization have a defined process to review and incorporate drawing revision/changes, to review the requirements, determine the contractual impact, notify applicable buyers of the impact and take necessary actions to ensure compliance to requirements?

*Review of requirements related to the product (AS9100B-7.2.2d.)*

Does your organization identify potential risks, analyze the potential impacts, and take actions to mitigate negative effects, before taking orders from customers?

Does your organization produce records of such actions?

**Purchasing***Purchasing process (AS9100B-7.4.1a-e.)*

Is your organization able to have "customer-designated" approved suppliers?

Would your organization be able to "approve suppliers" via an organization-defined process, with a defined customer authority and Nadcap approval for special processes?

*Purchasing information (AS9100B-7.4.2d-j.)*

Does your organization practice an efficient communication while transferring purchasing information with its suppliers with a well flow down of requirements?

*Verification of purchased product (AS9100B-7.4.3.a-e.)*

Does your organization use a method (appropriate and effective) to verify purchased product?

*Raw materials*

Does your organization have a method to test each batch/lot of material and annual raw materials verification?

*Purchased product requirements*

Does your organization purchase raw materials / and or contract special processes from any customer-designated supplier?

**Manufacturing****Manufacture**

Does your organization manufacture high value added products, highly processed and manufactured complexly, occupying a high percentage of your installed capacity?

*Planning of product realization (AS9100B-7.1.e.)*

Does your organization practice maintenance and/or tool repair facilities? (internal and external)

If either of these is outsourced, do you establish controls to assure that product continues to meet all the requirements?

*Control of production and service provision (AS9100B-7.5.1.)*

Does your organization have a control plan, methods used at each operation to assure conformance of product, for control of production and service provision?

Does your organization account for all material to preclude the occurrence of nonconforming product being shipped to the customer?

*Production documentation (AS9100B-7.5.1.1.)*

Does your organization perform production documentation, where all personnel have availability to correct and current data during production operations?

*Control of production process changes (AS9100B-7.5.1.2.)*

Does your organization have a control and documentation process for production process changes?

*Control of production equipment, tools and numerical control (NC) machine programs. (AS9100B-7.5.1.3.)*

Does your organization have control of production equipment, tools and numerical control machine programs?

*Control of work transferred on a temporary basis, outside the organization's facilities (AS9100B-7.5.1.4.)*

Has your organization developed/defined effective controls of work transferred on a temporary basis, outside the organization's facilities, to assure that only conforming product reaches the customer?

*Control of service operations (AS9100B-7.5.1.5.)*

Does your organization have a defined control of service operations?

### **Special Processes**

#### *General Requirements*

Would your organization be able to start a process in order to get a certification for its special process?

#### *Properties of Parts*

Would your organization be able to maintain all necessary documentation and data for each part that has a special process applied, for any future traceability?

#### *Validation of processes for production and services provision (AS9100B-7.5.2a & c.)*

Would your company be able to validate its special processes by the customer and/or by a Nadcap certification? Special processes require being qualified and approved prior to production.

### **Measurement and Analysis**

#### *Statistical Control Methods*

Has your organization implemented measurement device control?

Has your organization implemented any statistical process control in critical manufacturing and processing?

#### *Control of monitoring and measuring devices (AS9100B-7.6 & f.)*

Does your company have instruction documentation regarding gauge calibration systems, as a control of monitoring and measuring devices?

### **Supplier Audits**

#### *Customer audits of suppliers*

Has your organization been audited by customers based on risk analysis?

#### *Supplier internal audits*

Does your organization maintain an internal audit system?

Does your organization maintain control of all sub-tiers?

#### *Internal audit (AS9100B-8.2.2.)*

Is your organization able to practice internal audits and produce records of it?

### **Human Resources (HR)**

Does your organization have workers certified by customers for special processes?

Does your organization maintain good managerial skills at all levels?

## **Logistics**

### **MTO**

Does your company work on a Make To Order basis?

Has your organization worked with a high mix of customers in a low volume production and producing a high mix of products before?

### **Delivery**

Does your company have any standard order lead time from order receipt to shipment?

### **Preservation of product. (AS9100B-7.5.5a-f.)**

Is your organization committed to maintain the integrity of product after manufacture through all phases of the delivery process?

### **Product identification**

#### *Part Marking and Serialization*

Does your organization have a part making and serialization system?

#### *Identification and traceability. (AS9100B-7.5.3& a-d.)*

Is your organization able to use identification "labels" to indicate acceptance of processes or products and to practice traceability of product?

### **Service and warranty**

#### *Control of Material at the Supplier*

Does your company control the supplier material?

#### *Repairs*

Does your organization document performed repairs and rework?

## **Infrastructure**

### **Certifications**

Would your company be interested in getting the AS9100 and/or Nadcap certification(s) in order to be supplier in aerospace industry?

Does your company have a plan in place for 3<sup>rd</sup> party (registrar) certification to AS9100?

Is your company able to provide raw material with certifications through own company source?

Do you use a coordinate measuring machine (CMM)?

What other methods do you use to check parts?

If you do not currently have certified Quality Systems, are there plans to obtain certification? Which certifications and when?

Does your company practice Advanced Product Quality Planning (APQP)?

Do you calculate a Parts Per Million (PPM) defect rates?

Are you in the process of certification (please list which certifications)? When do you expect to be certified?

### **Tooling**

Does your organization produce maintenance and/or tool repair records?

Does your company audit tooling requirements from customers?

Do you build your own production tooling?

### **Information Technologies**

Does your organization have an ERP/MRP system capability?

Do you think your company currently supports advanced technology-enabled systems?

Do you think your company currently supports advanced software systems?

### **Financial**

Would your company be able to invest in equipment, if necessary, in order to enter into the aerospace industry?

How do you rate your company cash flow?

How much does your company sell per year?

How quickly do you qualify your inventory rotations?

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