
THE PHILIPPINES

IN THE AEROSPACE
GLOBAL VALUE CHAIN

MAY 2016

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The Philippines in the Aerospace Global Value Chain

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Acronyms

AAR	AAR Corporation
AIAP	Aerospace Industries Association of the Philippines
AIROD	Aircraft Inspection, Repair and Overhaul Depot
AMC	Applied Machining Corporation
APEC	Asia Pacific Economic Community
BASA	Bilateral Air Safety Agreement
BC	Baja California
CHED	Commission for Higher Education, Philippines
CORFO	Corporación de Fomento de la Producción (Chilean Economic Development Agency)
CTRM	Composite Technology Research Malaysia
DGAC	Dirección General de Aeronáutica Civil
DOD	U.S. Department of Defense
DOLE	Department of Labor and Employment, Philippines
DOST	Department of Science and Technology, Philippines
DTI	Department of Trade and Industry, Philippines
DTI-BOI	Department of Trade and Industry-Board of Investors, Philippines
EASA	European Aviation Safety Agency
EDB	Economic Development Board, Singapore
EPZ	Export Processing Zone
EU	European Union
FAA	Federal Aviation Administration
FDI	Foreign Direct Investment
FEMIA	Federación Mexicana de la Industria Aeroespacial (Mexican Aerospace Federation)
FSPMI	Famous Secret Precision Machining
FTA	Free Trade Agreement
GSP	Generalized System of Preferences
GVC	Global Value Chain
HS	Harmonized System
IAQG	International Aerospace Quality Group
IMMEX	Industria Manufacturera, Maquiladora y de Servicios de Exportación
IPP	Investment Priority Plan
IT	Information Technology
LCA	Large commercial aircraft
MIDA	Malaysian Investment Development Authority
MIGHT	Malaysia Industry-Government Group for High Technology
MHI	Mitsubishi Heavy Industries
MNC	Multinational Corporation
MRO	Maintenance, Repair and Overhaul
NADCAP	National Aerospace and Defense Contractors Accreditation Program
NAFTA	North American Free Trade Agreement
NASA	National Aeronautics and Space Administration
OASIS	Online Aerospace Supplier Information System
OEM	Original Equipment Manufacturer

OJT	On-the-job training
PADC	Philippine Aerospace Development Corporation
PAL	Philippines Airlines
R&D	Research and Development
SEIPI	Electronics Industry Association, Philippines
SME	Small and Medium Sized Enterprise
STEM	Science, Technology, Engineering and Mathematics
STI	Surface Technology International
TESDA	Technical Education and Skills Development Authority
US	United States

Executive Summary

This report uses the Duke CGGC Global Value Chain (GVC) framework to examine the role of the Philippines in the global aerospace industry and identify opportunities for the country to upgrade. The Philippines is a newcomer to the growing global aerospace manufacturing industry. Although the country has been host to a major flight controls manufacturer since 1985, the industry really only began to expand within the past five to ten years. During this recent period (2007-2014), the country has rapidly ramped up its aerospace manufacturing exports, reaching US\$604 million in 2014 and more than tripling employment. The industry now employs 3,000 full time and 3,000 part time workers. Although still a very small player, accounting for less than 0.15% of the global industry, this incipient growth is promising. Both foreign firms and local suppliers that have established operations in the industry have already achieved some degree of upgrading within a short timeframe. These include expanding the product lines served, obtaining essential process certifications and upgrading beyond basic assembly operations to undertake additional manufacturing processes such as machining as well as initiating procurement and engineering functions in country.

The Aerospace Global Value Chain

The global aerospace industry is a multi-billion dollar industry, estimated to be worth over US\$650 billion in 2014, with global trade over US\$400 billion. The industry, which includes the development of aerospace systems for both the commercial and defense markets, is one of the largest producers of high-technology goods in the global economy. Key characteristics of the Aerospace GVC include:

- **The aerospace GVC is comprised of seven stages**, including research and development (R&D) and design, components manufacturing, sub-assembly, systems integration, post-sales services (e.g. parts supply, maintenance, repairs and overhauls (MRO)) and end-of-life activities. Sub-assemblies include airframes, propulsion engines, fuel systems, landing gears, avionics and flight control systems (flight, navigation and communication systems), electrical power supply, and interior fittings amongst others.
- **The civilian aerospace market is experiencing a period of strong growth** as a result of replacement of aging fleets, the surge in air traffic in developing countries and an ongoing shift towards more fuel-efficient planes. Boeing forecasts total commercial jet deliveries of 38,000 aircraft by 2035. Airlines in Asia are becoming important customers for new aircraft. Asia-Pacific accounted for one third of both Airbus and Boeing's 2015 deliveries. This strong global demand has resulted in aircraft manufacturers and their suppliers becoming increasingly focused on ramping up production, driving the need for additional manufacturing capacity in the industry. This has created opportunities for new actors to enter the industry.
- **The aerospace GVC is highly concentrated and is becoming more so as firms** consolidate in response to an increase in outsourcing by the leading integrators,

Airbus and Boeing. This supplier-driven chain is heavily dependent on sophisticated and expensive technology platforms developed by a very small number of firms who determine which other actors can participate in the value chain. Combined with low volumes, and high regulatory costs, these technological and financial barriers make the entry very difficult in manufacturing stages of the chain. This means location decisions for the industry are in the hands of a very small number of firms.

- **The industry has not globalized to the extent many initially predicted.** The manufacture of final aircraft is concentrated in a handful of countries home to major aircraft manufacturers: Brazil (Embraer), Canada (Bombardier), France, Germany (Airbus), and the US (Boeing) with China and India emerging as new players in final craft exports. Between 2007-2014, global trade in components and sub-assemblies has increased by approximately 25%;¹ yet, the sector remains consolidated with the top 20 supplier countries continuing to account for over 90% in most product categories and the top three countries concentrating almost 60% of the total industry. The only newcomers to enter the global top 20 during this period were India, Poland and Russia. The main players from the Global South that have emerged as participants in this industry are: China, India, Malaysia, Mexico, Poland, Singapore, South Africa, and South Korea.

The Philippines in the Aerospace Global Value Chain

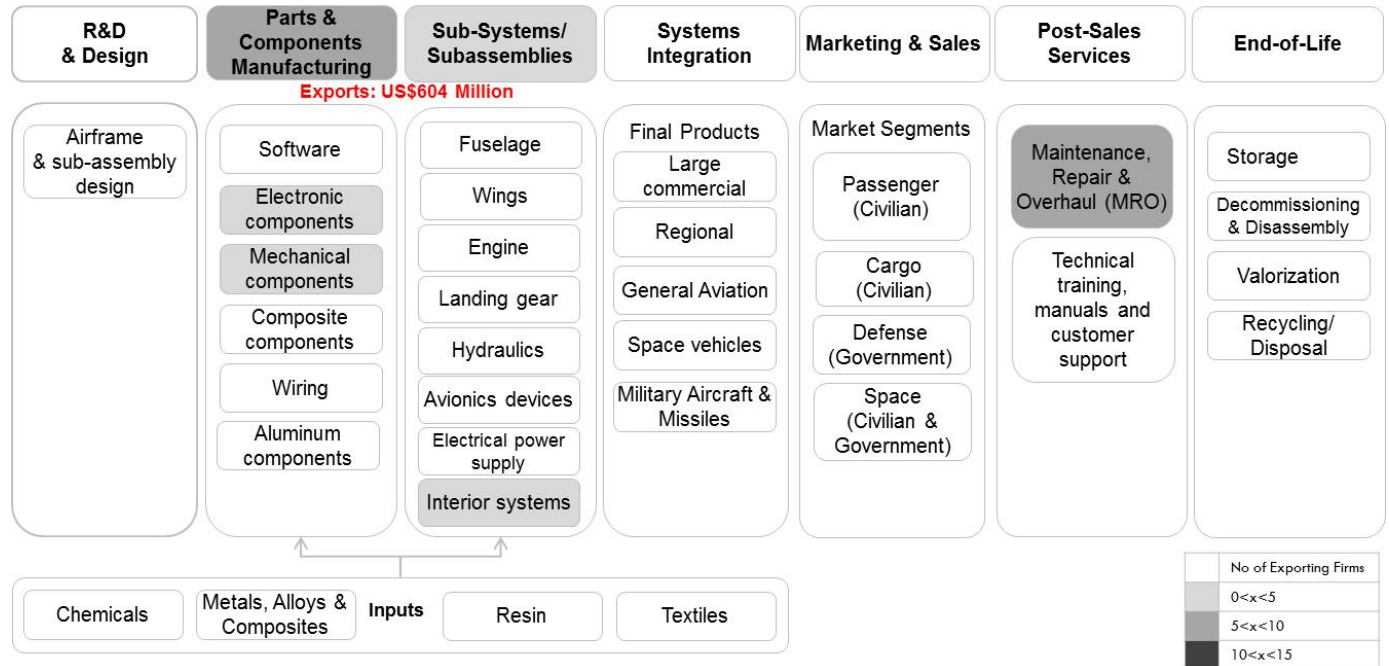
The Philippines is one of the newcomers to the aerospace GVC. Its incipient participation is concentrated in the manufacture and assembly of a small number of components and sub-assemblies in the interiors and flight controls systems, as well as some post-sales services such as MRO activities. Exports have accelerated in recent years, from almost negligible exports in 2010 to US\$604 million in 2014, 1% of the country's total goods exports. Exports are destined for several major aerospace manufacturing hubs, including a growing share to the European Union and the United States. Most firms sell directly into the primary manufacturing sector (i.e. plane assembly), however, at least one firm has already begun to sell into the more lucrative aftermarket. This early upgrading has helped create a total of 6,000 semi-skilled and skilled jobs, particularly amongst electrical, mechanical and industrial engineers, who account for close to half of employees in the sector.

The total number of firms in the sector is low but growing. Ten firms registered exports over US\$500,000 in 2014. Four Tier I firms are mainly production centers of global firms, which have engaged smaller local suppliers as they have sought to outsource more of their manufacturing operations. These foreign firms tend to be larger than their local counterparts – the largest two firms each have over 1,000 employees, and, although globally they attend more than one industry, they primarily serve the aerospace sector from their Philippines operations. Generally, local firms carry out machining and some finishing operations for components for these local Tier I firms, although they are beginning to develop some capabilities in direct exports. Geographically, these firms are dispersed; they are located mostly in EPZs in Luzon, to the North and South of Manila – in Baguio, Clark, Subic and the Batangas area.

¹ Excluding the US and UK components, which are reported together with final aircraft in trade statistics.

Figure E-I highlights the Philippine entry into aerospace GVC to date. No shading indicates no participation in the sector. Grey shading indicates there is at least one or more firm operating in the industry.

Figure E-I. Philippine Participation in the Aerospace Global Value Chain



Source: Authors.

The recent entry of the Philippines into the aerospace industry has been mainly organically driven, leveraging the country's large qualified, English-speaking human capital pool, competitive export processing zone (EPZ) incentives and the existing manufacturing capabilities developed while serving the regional and global automotive and electronics industries.

- **A large number of low-cost, qualified English-speaking engineers.** Local universities graduate approximately 60,000 engineers annually in mechanical, electrical & electronic, and chemical engineering, well suited to product manufacturing and there is growing interest in industry-specific skills development with aeronautical engineering and technical programs gaining popularity.
- **Experience in the automotive and electronics industry.** While significant upgrades are required to move from these industries into the aerospace sector, they provide two important baseline advantages: (1) personnel with experience working in MNCs driven by lean manufacturing principles, and (2) a supply base with CNC machining capabilities.

- **Improved policy environment for export-oriented firms.** The EPZs, overseen by the Philippines Export Zone Authority, are well-respected in the region and seen as an advantage by firms. This EPZ support has now been complemented by DTI-Board of Investments led efforts to coordinate public, private and academic stakeholders in the industry in preliminary steps to establish national objectives and incentives for the industry. Aerospace manufacturing is listed as a priority sector in the Investment Priority Plan 2014-2016.
- **Tariff-free Access to Key Markets.** Through the General Systems of Preferences in both the European Union (GSP+) and United States, the Philippines has tariff-free access to these key markets. India and the Philippines are the only GSP or GSP+ countries that operate in the aerospace sector in any significant way. Net imports in aerospace parts from Europe have surged in the past four years; from less than US\$500 million to close to US\$1.5 billion, as firms have brought the Philippines into their global production networks.

Certain efforts need to be made to overcome a number of key constraints to industry upgrading, including filling essential supply chain gaps, improving the regulatory environment for the aerospace sector – particularly with respect to bilateral and multilateral agreements on safety and export controls – and alleviating challenges in logistics and energy infrastructure and service.

- **Supply chain gaps.** Local suppliers only provide basic machining and processes. More high-end machining operations in multi-axis and precision machining are required. In particular, there are no firms yet providing NADCAP-certified processes in chemical or heat treatment for the industry or in working with composite materials. This means that products have to either be made in-house at Tier 1s or they have to be shipped to/from the US or other locations for painting, coating and other finishes, limiting further integration.
- **Lack of Key Regulatory Agreements** including Bilateral Aviation Safety Agreements (BASA) and membership in the Wassenaar Arrangement. The lack of existing BASAs in place with major aerospace manufacturing hubs places the Philippines at a disadvantage compared to its regional peers, Malaysia, Singapore and Vietnam. Firms must rely on agencies abroad to certify the airworthiness of their products, adding cost and delays. Export controls also do not yet comply with those outlined in the Wassenaar Arrangement and thus the country cannot manufacture components destined for the Defense sector. This also hinders access to dual-use technologies used for Civilian market products.
- **Logistics & Infrastructure:** Port congestion means that companies have to hold higher inventories of required raw materials and use more expensive shipping methods (e.g. air freight) in order to meet customer schedules. Although margins in the aerospace sector can allow for more expensive shipping options, these increase the cost to operations in the country and erode the advantages generated from labor arbitrage.
- **Energy Supply:** The cost and supply of energy is an economy-wide constraint to development. In this sector, it affects both the components manufacturing and assembly

stages in different ways. The components machining stage is a capital-intensive operation, with machines drawing considerable power. In the assembly stages, regulations require that operations be performed under specific and constant temperature conditions. In the tropical Philippines, this requires constant air-conditioning. With large production plants, energy quickly becomes the highest overhead costs and reliability is a key issue.

Upgrading in the industry in other countries has been heavily influenced by government policy and support, including tax incentives, proactive regulatory changes, training programs and a national strategy for growth. The few developing countries that have upgraded in the industry have followed a similar approach – beginning with components and assembly before expanding into production engineering, procurement and distribution. A similar strategy is proposed for the Philippines. Table E-I details the upgrading trajectories identified for the Philippines to expand and upgrade its position within the aerospace GVC.

Table E-I. The Philippines and the Aerospace GVC: Upgrading Trajectories

Time Frame	Potential Upgrading Trajectory	Key Benefits	Philippines Challenges
Short Term	Process Upgrading: Deepening the Supply Chain to Strengthen Backward Linkages	<ul style="list-style-type: none"> • Increase backward linkages and local value add in production • Expand number of products produced • Diversify market opportunities for automotive suppliers • Semi-skilled & skilled employment creation 	<ul style="list-style-type: none"> • Lack of availability of qualified & experienced personnel • Weak access to finance for supplier firms • Information asymmetries regarding capabilities impede linkage formation • High energy costs
	Product upgrading in the Interiors and Flight Controls Systems*	<ul style="list-style-type: none"> • Higher returns per product, highly skilled employment and enhancement of knowledge capabilities • Build credibility as a location 	<ul style="list-style-type: none"> • Supply chain gaps (e.g. processes) for manufacturing • Lack of human capital with relevant qualifications and experience • High energy costs
Short to Medium Term	Product Upgrading: Entry into Electrical Systems	<ul style="list-style-type: none"> • Leverage strong wire harness experience in automotive sector • Semi-skilled & skilled employment creation 	<ul style="list-style-type: none"> • Low-cost competitor in Mexico close to final assembly sites • Poor transportation infrastructure • High energy costs
	Functional Upgrading into MRO Service Provision	<ul style="list-style-type: none"> • Enter into services operations • Employment generation 	<ul style="list-style-type: none"> • Infrastructure in Manila airport is at capacity • Regional competition
Medium to Long Term	Market Upgrading: Geographic	<ul style="list-style-type: none"> • Increase reach of suppliers beyond the existing Tier 1s in the country – to serve other Tier 1s in the region 	<ul style="list-style-type: none"> • Lack of business connections • Weak procurement and forecasting skills • High energy costs • Weak logistics skills
	Market Upgrading: Entry into After-market Segment	<ul style="list-style-type: none"> • Much higher returns for same products 	<ul style="list-style-type: none"> • Logistics system unreliable from Manila • No local distributor of raw materials; suppliers must maintain stocks of costly inventory in-house

Source: Duke CGGC.

I. Introduction

The Philippines is a newcomer to the growing global aerospace manufacturing industry. With global trade of over US\$400 billion, the development of the aerospace sector offers the country potential to increase export revenues, gain access to sophisticated manufacturing technologies and create better opportunities for its highly educated workforce. Although the country has been host to a Tier 1 flight controls manufacturer since 1985, the industry really only began to expand within the past five to ten years. During this recent period (2007-2014), the country has rapidly ramped up its aerospace manufacturing exports, reaching US\$604 million in 2014 and more than tripling employment. The industry now employs 3,000 full time and 3,000 part time workers. Although still a very small player, accounting for less than 0.15% of the global industry, this incipient growth is promising. Both foreign firms and local suppliers that have established operations in the industry have already achieved some degree of upgrading within a short timeframe. These include expanding the product lines served, obtaining essential process certifications and upgrading beyond basic assembly operations to undertake additional manufacturing processes such as machining as well as initiating procurement and engineering functions in country. The objective of this report is to identify more precisely how these firms are participating in the global aerospace sector to help guide Philippine policy makers in their efforts to promote the industry.

With small numbers of annual aircraft deliveries – Airbus and Boeing delivered fewer than 1,000 planes each in 2015 (Airbus, 2016; Boeing, 2016), the global aerospace industry is characterized by low volume, high mix manufacturing and is heavily dependent on the availability of qualified engineers. High development costs, with a very small number of firms mean that products are high value and high margin. Strong industry demand is also driving global manufacturers to look for locations with competitive costs and capabilities to expand their production. This makes the industry well suited to the Philippines; the country has a large number of available, low-cost, English-speaking engineers. At the same time, the high industry margins allow the sector to circumvent the challenges of poor port logistics and infrastructure, to some degree, by using airfreight. Taking advantage of these opportunities to enter the industry, however, is very challenging. The industry remains highly consolidated around a small number of countries and companies; even though many have tried, few developing countries have been able to successfully establish their positions within the chain. Concerns over safety and security have resulted in some of the highest regulatory requirements in global manufacturing industries covering not only product characteristics, but also raw materials, processing and chains of custody as well as the export of specific technologies.

This report uses the global value chain (GVC) framework to analyze the Philippine's current position and potential for upgrading in the aerospace GVC. GVC analysis examines the full range of activities that firms and workers around the globe perform to bring a product from conception to production and end use. It examines the labor inputs, technologies, standards, regulations, products, processes and markets in specific segments and international locations, thus providing a holistic view of the industry both from the top down and the bottom up (Gereffi & Fernandez-Stark, 2011). Understanding how value is generated and controlled in the industry and analyzing the potential to shape domestic resources for use in the industry provide developing country policy makers useful information to identify trajectories for entry, growth

and upgrading along that chain.

The report is structured in the following way. Section two provides an overview of the aerospace value chain and a discussion of the key segments. This section presents the global trade, governance structure, upgrading and workforce development aspects of GVC analysis. By analyzing the global dynamics of the industry, these discussions provide essential foundational knowledge regarding sector competitiveness for the development of a strategic plan for industry entry and upgrading in the Philippines. Section three examines the upgrading experience of Mexico and Malaysia in the GVC for lessons to inform the Philippines policy development and identify potential upgrading trajectories for the country. Section four provides an analysis of the Philippines current contributions to the global aerospace sector. Challenges that could potentially undermine attempts to upgrade and grow further are also discussed. Finally, recommendations are made as to the potential upgrading trajectories open to the Philippines in this sector at this time.

2. The Global Aerospace Industry

The global aerospace industry is a multi-billion dollar industry, estimated to be worth over US\$650 billion in 2014 (Deloitte, 2015b).² The industry, which includes the development of aerospace systems for both the civilian/commercial and defense markets, is one of the largest producers of high-technology goods in the global economy. A number of divergent forces are currently shaping the global industry and opportunities for different firms and countries around the world—including the Philippines—to participate in the sector. These forces are affecting the demand for specific models of planes as well as where and how these are manufactured.

First, the civilian aircraft segment of the industry continues to experience a period of strong growth as a result of replacement of aging Western fleets, the surge in air traffic in developing countries, particularly in the Asia Pacific region, and an ongoing shift towards more fuel efficient planes.³ This is particularly notable for the redesigned regional jets, such as the Boeing 737MAX and the Airbus 320neo (Airbus, 2016; Boeing, 2016; S&P Capital IQ, 2015).⁴ With order backlogs for commercial planes at record levels, aircraft manufacturers and their suppliers are increasingly focused on ramping up production (Mecham, 2013b). This is driving strong demand for additional manufacturing capacity in the industry. Second, significant cuts in defense spending, particularly by the US government, are resulting in lagging demand for military aircraft and, as a result their components and sub-assemblies (Deloitte, 2015b; S&P Capital IQ, 2015); Rolls Royce, for example, saw defense revenue drop by 20% in 2014 alone (Rolls Royce

² This is the higher than total trade in the industry as it includes domestically produced and consumed products as well as traded products.

³ Demand driven by the need for increased fuel efficiency is expected to decline slightly in the face of the current low oil prices, however, the long term tendency will continue in this direction.

⁴ In addition, while demand for passenger jets is rising, demand for specialized cargo planes is declining as logistics operators switch to the use of 'belly cargo' in the wide-body passenger jets such as the 787 and the A350, which can accommodate large amount of cargo in addition to passenger weight (Flight Global, 2012; Johnsson, 2014; Schofield, 2015).

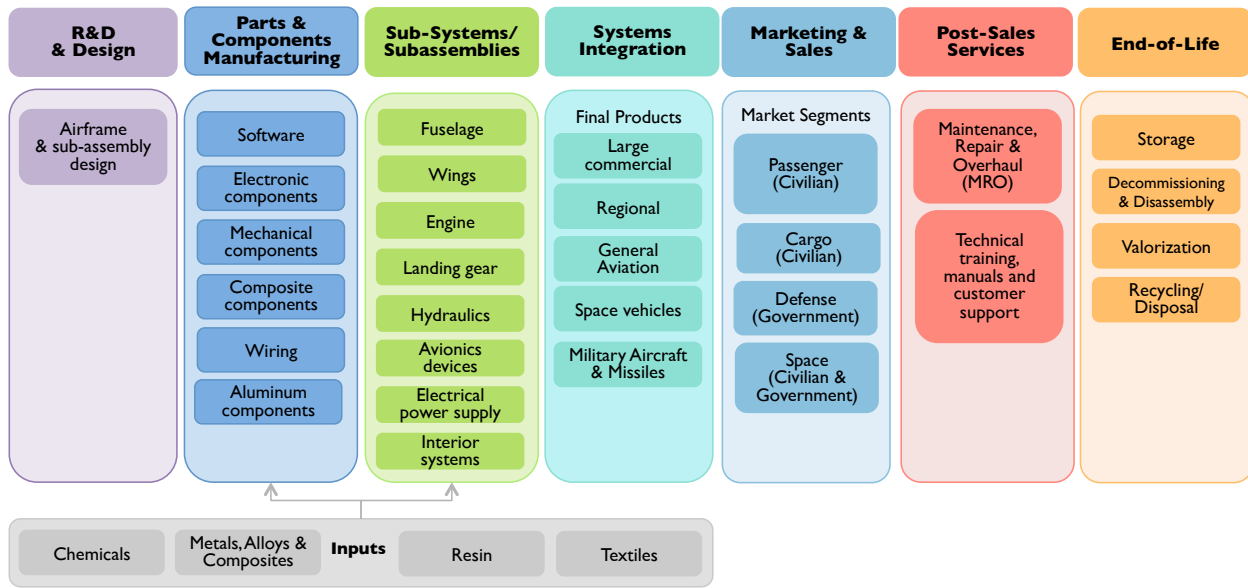
Holdings, 2015). With strong demand for commercial planes, manufacturers are considering re-working some of their existing military production lines to service demand for commercial jets. This is important as defense spending – far greater than the commercial market – is generally a strong driver of maintaining the industry in a small number of locations. Third, the new business models introduced in the manufacturing of the 787 Dreamliner and the A350 have ushered in a high level of production outsourcing to the industry (Ehret & Cooke, 2010; Field Research, 2016). In particular, many Tier 1 manufacturers are focused on reducing their in-house production in favor of higher value design and development activities. As a result, this has created opportunities for the growth of Tier 2 suppliers around the world.

This report will focus principally on the civilian/commercial aerospace industry, as the Philippine aerospace sector does not yet serve the defense market due to global regulatory limitations on the export of dual-use technologies (see Section 4), as well as the current dip in global defense spending. In particular, the report will emphasize those sections of the industry whose final products include large commercial aircraft, regional jets, business jets and general aviation aircraft which fall within the scope of the current and potential activities of the country. However, most firms in this segment also design and manufacture aircraft for the defense segment and it is difficult to discuss the development of one segment without the other. The defense segment will thus be analyzed where products overlap with commercial aerospace products, but airborne weapons systems and related products are considered beyond the scope of this analysis.

2.1 Mapping the Aerospace Global Value Chain

Mapping the global value chain in any sector provides a powerful tool for understanding the scope and potential for industry growth as it allows policy makers to understand how industries can be disaggregated into different parts across geographic boundaries. There are seven principal stages of the aerospace global value chain (GVC),⁵ including research and development (R&D) and design, components manufacturing, subassembly and systems integration. Post-sales services and end-of-life activities have also become increasingly important, and profitable, parts of the industry. Figure 1 offers a visual representation of the GVC for aircraft manufacturing.

⁵ The aerospace manufacturing value chain is distinct from the aviation value chain in that it covers the process of the manufacture of products in the industry. The aviation sector is considered the target market of this industry. The aviation value chain, on the other hand, is a services value chain in which aircraft equipment and spare parts are provided as inputs for the industry. These two industries have very distinct sets of activities and are driven by different sets of firms.

Figure 1. Aerospace Global Value Chain


Source: Authors based on Bamber & Gereffi (2013)

R&D and Design: The R&D and design costs required to develop a product line in the aerospace industry are formidable. Product development generally lasts from five to ten years, and it is estimated that it takes 10 to 18 years for an aircraft to become profitable (Niosi & Zhegu, 2010). These expenses result in considerable barriers to entry for new actors as well as in a relatively small product group. The two most recent introductions, the Boeing 787 Dreamliner and the Airbus A350 development costs were over US\$15 billion each (Gates, 2011; Leggett, 2013). Globally, there are fewer than ten major companies engaged in the overall development of new commercial planes. With growing costs and complexity in R&D and design as technological advances are made, operations have been increasingly shared with specialized systems providers, such as engine and airframe developers who engage simultaneously with the final aircraft manufacturer in the design of systems for new planes. In these cases, they are referred to as ‘risk partners’, as compensation is based on the final sales of the final craft. Under this new model, these partners retain the ownership of their systems and thus may sell them to other systems integrators in the future (Tang & Zimmerman, 2009).

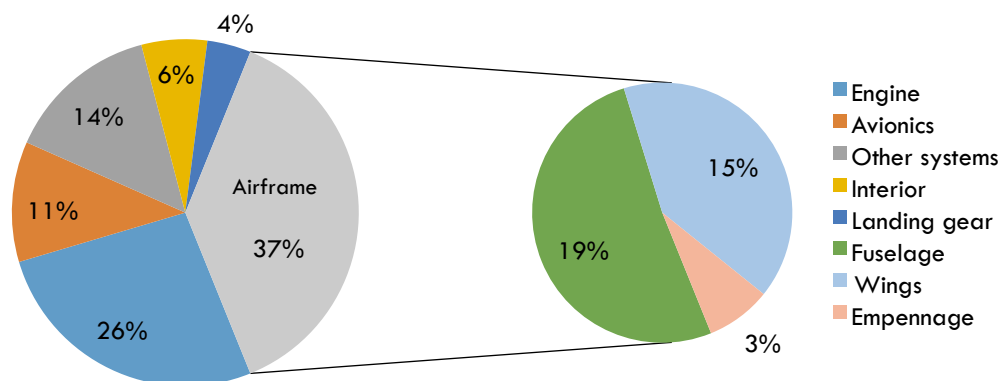
One of the most important changes in recent years in R&D technology has been the introduction of composites technology, which has helped to significantly reduce weight while increasing strength and durability. Composite materials are extensively used in modern aircrafts and its use is expected to grow because of the benefits of being lightweight and having high strength-to-weight ratio. More than 50% of A350, and 25% of A380 are composite parts (MIGHT, 2015).

Parts and Components Manufacturing: This segment of the chain includes the specific and generic inputs required to form the sub-assemblies of the aircraft. Such components range

from circuit boards and sensors to composite parts for the empennage (tail of the craft) to specialized fasteners and screws used in tray tables. This manufacturing process includes materials planning and procurement, fabrication of the parts, assembly and routine testing (APEC Policy Support Unit, 2015). This segment of the value chain is dominated by firms which manufacture product- or industry-specific components such as rotors, antennas and motors, and firms which manufacture more generic components including un-machined castings and whose portfolio of clients often includes non-aerospace customers. Firms operating in the component segments may also manufacture components for other industries such as the automotive and industrial sectors. Some parts manufacturers, particularly in consumables such as screws and fastener producers, may not sell their products directly to the downstream actors, but rather use large specialized distributors, such as KLX which have highly sophisticated, global distribution networks and serve both integrators and MRO clients (Field Research, 2016).

Sub-assemblies or Sub-systems: Sub-assemblies are the modules that the aircraft manufacturer assembles into the final product. These sub-assemblies include airframes, propulsion engines, landing gears, avionics and flight controls systems (flight, navigation and communication systems), electrical power supply, fuel systems, and interior fittings amongst others. The relative value of sub-assemblies is shown in Figure 2. While the airframe is the most expensive, it should be noted that this “component” is made up of several modules (the wings, the center wing box, the front fuselage, the aft fuselage, the empennage and the nose), whose production is shared across multiple firms spread across several countries. The relative value of these assemblies has begun to change – with few major new planes in development, engines, wings and interiors will all become more lucrative segments as manufacturers seek to make existing models more efficient and more cost-effective (Field Research, 2016). Firms operating at this stage of the value chain include those that produce final assemblies; as noted above, they have also increasingly taken on a ‘risk-sharing’ role in the R&D for sub-systems of new aircraft.

Figure 2. Value of Subsystems as a Percentage of the Total Aircraft Value



Source: Wipro (2009).

Final Assembly & Systems Integration: Systems integration refers to the process of connecting the various systems and subsystems that constitute the aircraft into a “complete system.” For example, flight controllers in the propulsion system must be able to monitor and respond to changes registered in the avionics system. Final aircraft manufacturers have been moving towards a business model based around systems integration since the 1980s (Niosi & Zhegu, 2010; Christen Rose-Anderssen et al., 2008). This has moved systems integration from a multi-month activity to one of less than a week; the 787 Dreamliner, for example, can be assembled in less than a week (Tang & Zimmerman, 2009). Systems integration is controlled by the final aircraft manufacturer, although, as risk-sharing suppliers assume greater R&D and design roles, firms providing propulsion (engines) and avionics systems also play a role in systems integration, ensuring that the various subsystems properly communicate with one another.

Final products in the aerospace manufacturing market include large commercial aircraft (LCA), regional jets and general aviation aircraft (e.g. business jets, turboprops, helicopters, etc.) Due to high development costs, there are a limited number of final products in the LCA and regional jet operations, with fewer than 15 product families. While the military and general aviation segments have a larger number of product models, given the total cost of developing new commercial aircraft there are actually very few aircraft models on the market.⁶

Table 1. Principal Commercial Aircraft Families by Leading Integrators, 2016

	Airbus	Boeing	Bombardier	Embraer
Commercial Jets (Wide-body)	A350, A380	777, 787		
Regional Jets (Single Aisle)	A320, A320Neo, A330	737, 737 Max	CRJ700, 900, 1000 CS100, 300	E170, E175, E190

Source: Airbus (2016); Boeing (2016); Bombardier (2015).

Marketing and Sales: There are four principal end market segments in the industry: the commercial passenger segment, which includes buyers ranging from airlines and lessors such as Philippines Airlines (PAL), Cathay Pacific and Singapore Airlines, and International Lease Finance Corporation and General Electrical Capital Aviation Services (lessors) to businesses and medical rescue operations to individuals; cargo operations, including firms such as DHL, Fedex and UPS. Commercial airlines may also be state-owned enterprises, in which case the buyer can be a national government.⁷ Marketing and sales is primarily the domain of final aircraft manufacturers, however, in some cases, such as the Boeing 787, alternative engine options from

⁶ For example, a total of 2,454 planes manufactured for the general aviation segment (excl. helicopters) in 2014. 88% of these planes were manufactured by the top ten firms (Aeroweb, 2015a).

⁷ In large markets, where a state-owned enterprise has considerable buying power, they can use these to require manufacturers to engage in offset agreements; that is, they can require final aircraft integrators to purchase sub-assemblies or components from firms in-country. This practice is considered against the free trade principals promoted by the World Trade Organization (Bamber & Gereffi, 2013).

Rolls Royce and General Electric (GE) mean that these firms must also engage directly in marketing and sales to final customers.

After-Market: Post-production services include after-market parts supply as well as maintenance, repair and overhaul services (MRO), technical training and customer support and the supply of flight simulators. Aircraft maintenance is carried out after specific times and/or mileage and is a substantial part of total aircraft cost. Supplying parts to this segment requires effective distribution networks and the ability to manufacture using a very high mix, low volume approach as parts demand is often one-off and required within a 24-36 hour period (Field Research, 2016). As a result, the way firms provide after-market services has changed over time in order to maintain competitiveness, from in-house inventory holding to inventory hosting by a service provider (APEC Policy Support Unit, 2015). As global aircraft fleets expand, the after-market is becoming an increasingly important revenue generator; for some manufacturers, the supply of parts to MRO operations account for over 50% of their revenue. In some cases, parts supplies can be sold at three times the price of sale to manufacturers (Field Research, 2016).

Box 1. The Maintenance, Repair and Overhaul (MRO) Market

Aircraft maintenance is carried out after specific times and/or usage and is a substantial part of total aircraft cost. It has thus become an important segment of the aerospace market. Global commercial MRO spending is estimated to reach US\$63.2 billion in 2016 and is expected to grow to US\$90.5 billion by 2025 (Broderick, 2016b). Airlines, third-party providers and OEMs all compete in this lucrative segment. OEMs dominate a growing portion of the market as they move towards a full-service business model. Driven initially by engine OEMs using strategies such as limited access to technical manuals, parts and tooling, thus making services certifications more difficult to obtain, OEMs have increased their participation in this after-market.

Aircraft maintenance checks can be classified as engine overhaul, components overhaul, line maintenance, heavy maintenance, avionics or retrofit (see Table 2), with engines maintenance and repairs accounting for the largest share of MRO spending. MRO firms may be specialized in one area, such as engines or avionics, or offer an integrated service. Co-locating with other MRO firms with complementary expertise can also provide competitive advantage. For example, Singapore is the leading provider of integrated MRO services in the Asia-Pacific region, thanks to the presence of OEM and third-party MRO providers in avionics, engines and airframe maintenance as well as a components manufacturing sector. Engines will continue to account for the majority of MRO revenue, followed by components. In the face of rising fuel costs and new regulations, there has been strong emphasis placed on improving engine technologies for fuel efficiency such as fuel burn reduction washes and R&D in hybrid engine technology.

The single most important driver of the MRO segment is air transportation, with regional fleet size and projected growth providing strong indicators for demand. Geographic consideration for a firm's global footprint is crucial. MROs need to have major facilities in key traffic flow areas, as it is expensive to fly planes long distances for maintenance requiring just a few man-hours. At the same time, nonetheless, leveraging low-cost locations, skilled labor and quality performance for non-geographically sensitive work such as component MRO and more intensive maintenance work, is also important for sustaining competitiveness in the long term. As a result of balancing these needs for geographic sensitivity and utilizing low-cost locations, today many MRO firms have established global networks servicing multiple different clients.

Table 2. MRO Service Activities

Type of MRO	Description of Activity	Forecast Market Share (2016-2025)	Geographic Sensitivity	Firms
Engine overhaul	This ranges from routine service checks to the complete repair of the engines.	36%	Global, low-cost, specialized locations	Lufthansa Technique Rolls Royce GE Aviation
Components overhaul	This usually involves the overhaul of all parts not categorized under heavy-maintenance. These range from landing gear to fuselage overhauls.	22%	Global, low-cost, specialized locations	Hawker Pacific Aerospace Ameco
Line maintenance	This function involves the routine maintenance of the aircraft as well as frequent inspection of the aircraft to ensure its safe in-service use and minor repairs as advised or required by OEM periodic publications.	26%	Local, limited man-hours, in airport hubs	Scandinavian Aircraft Maintenance SIA Engineering
Heavy maintenance	This usually involves the disassembly of major components of the aircraft for detailed inspection and repairs.	14%	Global/Regional low-cost, specialized locations	AAR Corporation SR Technics ST Aerospace
Avionics	MRO organizations in this category specialize mainly in the overhaul of the aircraft avionics and associated components.		Global, low-cost, specialized locations	Honeywell Selex Galileo Global
Retro-fits and conversions	This sector is responsible for the major and minor design retro-fits of interiors and the conversion of passenger aircrafts to freighter aircrafts.		Global, low-cost, specialized locations	Aeronautical Engineers Airbus Haeco

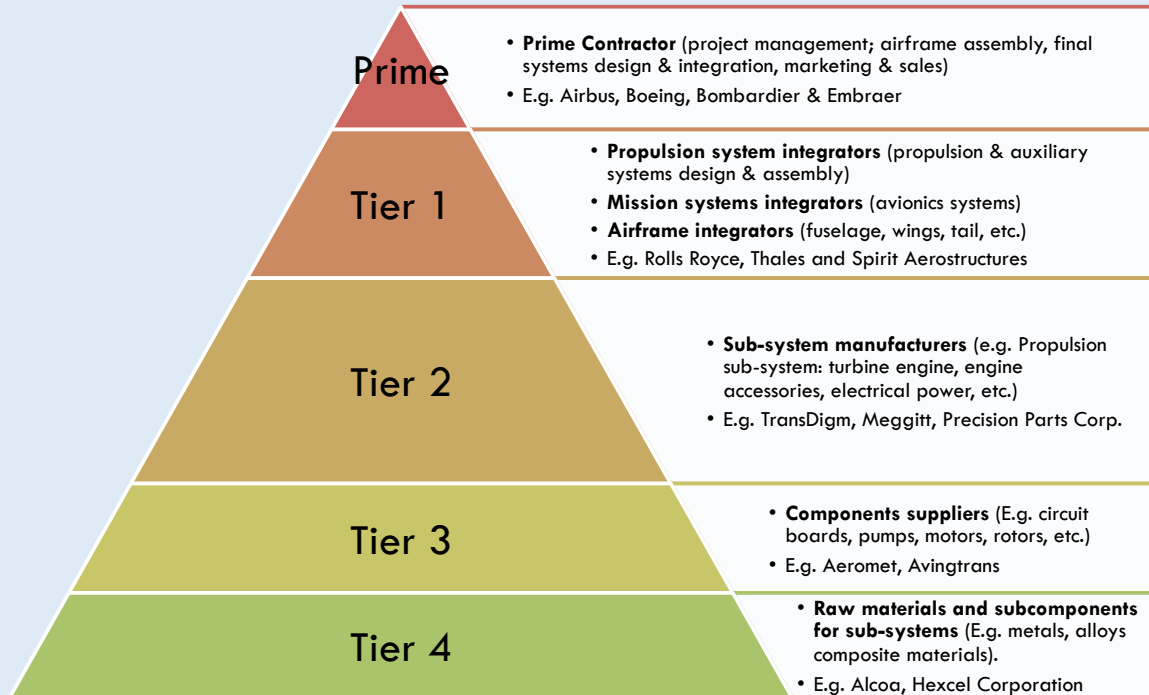
Source: Bamber & Gereffi (2013)

End-of-Life: This segment of the value chain encompasses the retirement of an aircraft after its useful flying life. The aircraft is decommissioned and disassembled with working parts refurbished and destined for the spare parts after-market, while non-useable parts are recycled or trashed (Towle, 2007). While there are not yet legal requirements for manufacturers to manage end-of-life operations for their products as in the European automotive industry, this services segment has been growing steadily as the industry awareness of improving the disposal of their aircraft has increased and other investors have identified this as opportunity to earn important returns (PwC, 2013; Ribeiro & Gomes, 2015). An estimated 12,000 planes will be retired over the next 20 years, providing a large number of after-market parts (AFRA, 2015). Currently, this segment is served by non-manufacturing third-party providers, such as Aircraft Demolition and Aircraft-End-of-Life Services. Due to the importance of ensuring that recycled parts are in adequate condition, there is a strong drive to regulate this sector (Barker, 2013).

Box 2. Supply Chain Relationships in the Aerospace Manufacturing Sector

This box provides a brief description of the various suppliers in the global aerospace industry and the relationship between them. The tiered supply structure has become increasingly differentiated following changes to the aerospace supply chain in recent decades, as all actors in the chain have sought to improve their competitiveness. Figure 3 provides an overview of the different tiers, a description of the role each performs within the value chain and examples of the products each yields.

Figure 3. Tiered Supply Chain Structure



Source: Authors based on Sturgeon et al. (2013).

Changes introduced with the new business models developed for the 787 and the A350 have resulted in increased overlap in the tier structure as Tier 1 firms seek to outsource production to Tier 2 and 3 suppliers, while specialized Tier 4 suppliers seek to upgrade their outputs into the Tier 2 and 3 stages. This is resulting in Tier 3 firms being squeezed out of the sector. This indicates that, despite increased outsourcing, it could become increasingly difficult for smaller Tier 3 companies in developing countries to enter the chain or remain competitive, and these countries may need to attract large global Tier 2 providers in order to support industry growth. See Section 2.3 for further discussion of the forces reshaping the industry.

2.2 Global Trade in the Aerospace Global Value Chain

Global trade including components, sub-assemblies and final aircraft has increased significantly over the past decade as growth in the industry has increased the total number of planes being manufactured. This has encouraged developing countries to seek entry into the GVC. Based on a narrow definition of the industry,⁸ global trade has increased by 56% since 2007, from US\$271 billion to approximately US\$423 billion in 2014 (UN Comtrade, 2015).⁹ These trade figures related to the aerospace industry should, nonetheless, be interpreted with caution due to three key issues: First, due to the sensitive nature of the industry, there has been a tendency towards consolidating exports under generic and aggregate trade codes; and second, at the components level, there is considerable overlap with others sectors, such as the automotive and electronics sector. Finally, trade statistics may include the import and export of parts and aircraft that enter and exit a country for MRO services. Thus, while these figures likely underestimate the size of the industry's components and sub-assembly exports, they also over estimate some of the exports of sub-assemblies and final products. The analysis in this section thus draws on a number of sources in addition to trade data, including the data from leading manufacturers, to determine global trade flows.

Global Demand

As highlighted earlier in the report, global demand for commercial aircraft is driven primarily by major airlines and lessors expanding their fleet or replacing aging aircraft. This demand for final product has driven global trade in the components and sub-assemblies as suppliers look to expand their production bases to meet the new volumes (Field Research, 2016). Overall demand has been strong, following the sector's recovery from the 2009 economic crisis, and has continued to show robust backlogs despite recent concerns of the global economy. Boeing forecasts total commercial jet deliveries of 38,000 aircraft by 2035 (Airbus, 2016; Boeing, 2016; S&P Capital IQ, 2015). The US and European markets are the most mature markets, with steady growth predicted in the near future from the renewal of fleets, most of which are over 12 years old (S&P Capital IQ, 2015),¹⁰ and the introduction of more fuel efficient planes (Deloitte, 2015b).

At the same time, airlines in Asia and the Middle East are becoming important customers of new aircraft; the United Arab Emirates alone consistently accounted for approximately 5% of annual global imports, by value, over the past decade (UN Comtrade, 2015). Asia-Pacific accounted for 39.4% (195/495) and 36.5% (233/638) of Airbus and Boeing's 2015 deliveries respectively (Boeing, 2015; Airbus, 2015). In the past, developing countries often purchased mid-life aircraft driving a secondary market, however, with increased access to Export Credit from manufacturing countries, these countries are placing orders for new craft (PwC, 2013).

⁸ See Table A-I in the Appendix.

⁹ Statistics are difficult to track as two major players in the industry, the US and the UK, stopped reporting disaggregate trade statistics for the sector during this time period. All US aerospace exports are now included under the HS-88 code. This is likely due to the sensitive nature of the industry, given its role as a technology driver and its overlap with the defense sector.

¹⁰ For example, in 2015, the average age of the American Airlines fleet was 12.3 years; Southwest Airlines, 11.6 years; Delta Airlines, 17.2 years; United Airlines, 13.1 years (now merged with Continental); Lufthansa, 10.7 years; British Airways, 12 years; and, Air France, 11.4 years (S&P Capital IQ, 2015).

In the medium to long term, Airbus and Boeing predict the highest demand will continue to come from the Asia-Pacific region, accounting for some 30% of global deliveries (Deloitte, 2015a; S&P Capital IQ, 2015). China will likely account for the largest share of these deliveries – around 5,300 of the 14,300 aircraft – but South-East Asia is also going to be an important driver of demand with a forecast for 3,750 aircraft deliveries as the civil aviation market in the region is predicted to expand significantly over the next twenty years as the ASEAN Single Aviation Market is implemented (Boeing, 2015). For example, Philippines Airlines (PAL) recently placed an order with Airbus for six A350 aircraft, valued at approximately US\$1.8 billion (DW, 2016). Single-aisle, medium-haul planes, such as the 737 and A320 is the fastest growing market segment (Boeing, 2015). It is estimated that these currently account for 75% of global air traffic and this is likely to continue to grow (UPS, 2015).

Global Supply

On the supply side, the manufacture of aircraft is concentrated in a small number of countries home to major aircraft manufacturers: Brazil (e.g., Embraer), Canada (e.g., Bombardier), France, Germany (e.g., Airbus), and the US (e.g., Boeing) with China and India emerging as new players in final craft exports.¹¹ Global trade in components and sub-assemblies (excl. US & UK exports) has increased by approximately 25%¹² between 2007 and 2014; yet, this trade has not become as global as initially predicted. The sector remains consolidated with the top twenty supplier countries continuing to account for over 90% in most product categories and the top three countries concentrate almost 60% of the total industry (See Table 3).

Table 3. Top 20 Exporters of Manufactured Products in the Aerospace GVC, 2014

Exporter	Value (US\$ billions)				Share of World Aerospace Exports (%)			
	2007	2010	2012	2014	2007	2010	2012	2014
World Total	270,5	299,756	375,812	422,693				
US	104.4	81.7	102.9	120.1	39	27	27	28
France	39.2	55.5	64.9	69.9	15	19	17	17
Germany	31.9	39.0	54.4	54.6	12	13	14	13
UK	16.0	30.2	38.0	39.6	6	10	10	9
Canada	14.2	13.8	14.9	17.7	5	5	4	4
Singapore	5.2	7.2	9.9	11.4	2	2	3	3
Italy	7.2	8.5	9.4	10.8	3	3	3	3
Japan	5.7	6.1	8.7	9.3	2	2	2	2
India	0.5	1.9	2.1	7.5	0	1	1	2
Spain	4.4	4.2	5.4	6.1	2	1	1	1
Brazil	5.2	4.7	5.7	5.9	2	2	2	1
China	2.1	2.8	3.6	5.7	1	1	1	1
Switzerland	3.9	3.2	3.8	4.7	1	1	1	1

¹¹ India's primary manufacturer, Hindustan Aeronautics Limited (HAL), is focused almost exclusively on the defense market together with commuter taxi-planes and private helicopters.

¹² Excludes US and UK components and sub-assembly trade.

Netherlands	3.4	3.8	4.0	4.7	1	1	1	1
China, Hong Kong	1.9	2.6	3.2	3.7	1	1	1	1
Mexico	2.1	2.2	2.7	3.3	1	1	1	1
Russian Federation	1.1	1.4	2.6	3.1	0	0	1	1
Belgium	1.9	2.1	2.0	2.8	1	1	1	1
Poland	0.6	1.4	2.0	2.8	0	0	1	1
Israel	1.9	2.0	2.1	2.2	1	1	1	1
Top 20 in 2014	252,577	274,449	342,344	385,781	93	92	91	91

Source: UN Comtrade, HS02 6D codes, Reporters exports to the World, Retrieved 10/29/15

The main players from the Global South that have emerged as participants in this industry are: China, India, Malaysia, Mexico, Poland, Singapore, South Africa, South Korea and Thailand.¹³ However, the only newcomers to enter the global top twenty during this period were India, Poland and Russia at the expense of Austria, Sweden and Thailand. Indeed, Malaysia and Thailand both lost market share during this period. This highlights the complexity of entry into this competitive global industry.

Participation from select emerging players in the sector remains limited as is shown in Table 4.

Table 4. Select Emerging Players in the Global Aerospace Industry, 2007-2014

	Value (US\$, millions)				Share of World Exports			
	2007	2010	2012	2014	2007	2010	2012	2014
World Total	270,522	299,756	375,812	422,693	100%	100%	100%	100%
Singapore	5,225	7,220	9,932	11,449	2%	2%	3%	3%
India	503	1,900	2,055	7,456	0%	1%	1%	2%
China	2,086	2,816	3,595	5,734	1%	1%	1%	1%
Mexico	2,081	2,170	2,684	3,269	1%	1%	1%	1%
Russia	1,145	1,375	2,593	3,054	0%	0%	1%	1%
Poland	588	1,441	1,962	2,778	0%	0%	1%	1%
Rep. of Korea	948	1,651	1,557	2,163	0%	1%	0%	1%
Thailand	1,911	1,669	1,629	1,677	1%	1%	0%	0%
Ukraine	0	827	1,657	1,129	0%	0%	0%	0%
Malaysia	1,158	956	879	1,057	0%	0%	0%	0%
Czech Rep.	926	643	776	1,031	0%	0%	0%	0%
Turkey	901	495	781	909	0%	0%	0%	0%
South Africa	604	386	539	746	0%	0%	0%	0%
Philippines	298	6	129	255	0%	0%	0%	0%
Emerging players	18,374	23,555	30,768	42,708	7%	8%	8%	10%

Source: UN Comtrade, HS02 6D codes, Reporters exports to the World, Retrieved 10/29/15. US and UK data added for all HS88. This includes HS8801 and 8804 which are otherwise not included for other countries. Needed because U.S. only reports under HS880000 for 2009 onwards and UK did not report at the 6D level in 2007, 2010 or 2012.

¹³ Israel is also a top twenty country; however, they have focused primarily on the defense sector (Carrillo & Hualde, 2011).

Singapore has been the most successful new entrant into the industry, carving out a 3% market share with US\$11.4 billion in exports in 2014. Singapore has built its product export industry based on a focus on the engine and propeller product segment which together account for half the country's exports (Bamber & Gereffi, 2013). Over 50% of its exports go to traditional manufacturing hubs, although regional exports (excluding China) doubled between 2007 and 2014 to US\$2.2 billion (see Table A-2 in the Appendix for specific exports and destinations). Singapore is followed by **India**, which has seen a very fast expansion of its exports over the past seven years reaching US\$7.5 billion in 2014. India's dramatic growth is to a large degree thanks to the expansion of its domestic aviation sector, complemented with offset agreements which have helped develop a local supply base, and almost more importantly, defense exports (AT Kearney, 2009; Moser et al., 2012). In 2014, it exported US\$2 billion and US\$1.2 billion of helicopters to Sri Lanka and United Arab Emirates, respectively. **Mexico's** exports are more diverse, with the country operating in several different product segments. Mexico's growth in the industry has been based to a significant degree on its role as a lower cost supplier to the North American aerospace sector (see Section 3). In 2014, for example, 89% of exports were destined for the US and Canada. Finally, **Poland** is the fourth largest new player. Poland has leveraged its longer trajectory in aerospace design and manufacturing to enter the global industry. Almost all Polish exports are in the engine and propulsion category.

2.3 Lead Firms and Changing Governance Structures in the Aerospace GVC

The aerospace industry is heavily dependent on sophisticated and expensive technology platforms developed by a very small numbers of firms who determine which other actors can participate in the value chain. Combined with low volumes, and high regulatory costs, these technological and financial barriers make the entry into this 'supply driven chain' very difficult. This keeps the number of firms low, and also places locational decisions for the industry in the hands of just a few decision-makers. Key features of how these lead firms in this supplier-driven chain interact, and the distribution of power amongst them, are highlighted below.

The commercial aerospace industry is dominated by a small number of lead firms at the prime/integrator level (large, regional and business jets and general aviation segments). Low overall volumes and sophisticated technology requirements, combined with high regulatory costs for certification and costly development programs, limit entry into this segment. The wide body market of large commercial jets consists of an oligopoly with Airbus and Boeing each controlling approximately half of the market by the end of 2014 (Airbus, 2015); the market has been fairly evenly split over the past ten years. The regional narrow body jet market is only slightly more diverse with Bombardier (Canada) and Embraer (Brazil) joining Airbus and Boeing as well as new challengers in emerging primes, COMAC (China) and Mitsubishi Heavy Industries (MHI) (Japan) (S&P Capital IQ, 2015).¹⁴ The business jet and general aviation segments are also quite concentrated, with Gulfstream, Falcon

¹⁴ The MRJ 90 flew its inaugural test flight in November 2015 (Harding, 2015), while the C919 is expected to fly in 2016/7 (Toh, 2015).

Jet and Textron Aviation taking the lead. Table 5 highlights these leading aircraft integrators by segment. While many of these lead firms also operate in the defense sector, that market also includes very strong actors such as Lockheed Martin, Northrup Grumman and Raytheon which are exclusively focused on serving the military market (PwC, 2014).

Table 5. Leading Prime Integrators in the Civilian Aerospace Sector, 2014 By Revenue

Company	HQs	Revenues (US\$ billions)	Employees	Role in Aerospace GVC (Main Product Segment)
Boeing	US	90,8	165,529	Final craft (commercial jets)
Airbus (EADS)	France	80,7	138,622	Final craft (commercial jets)
Bombardier	Canada	10,5	74,000	Final craft (regional jets)
Gulfstream (General Dynamics)	US	8,6	+15,000	Final craft (business jets)
Embraer	Brazil	6,4	19,167	Final craft (regional jets)
Falcon Jet (Dassault)	France	4,9	12,000	Final craft (business jets)
Textron Aviation	US	4,6	10,800	Final craft (general aviation)

Source: Authors based on S&P Capital IQ (2015) and 2014 company annual reports.

Note: MHI and COMAC are not included as their aircraft have not yet been delivered.

Over the past few decades, these firms have sought to rationalize their supply base around a smaller number of increasingly capable systems suppliers (mission critical and otherwise). As highlighted earlier, these suppliers are considered ‘risk-sharing partners’ and are directly engaged in the R&D of new aircraft. In a highly competitive market, firms have sought to gain advantage by introducing more fuel-efficient planes at lower costs more quickly than their competitors. By leveraging the capabilities of these suppliers at the R&D phase, firms can design and manufacture new planes with shorter lead times and lower financing costs. Suppliers have been attracted to these deals, as they can secure long-term, often sole-sourcing contracts – up to 45 years, while retaining ownership of the intellectual property, allowing for sale to other buyers. Under this arrangement, suppliers are responsible for all aspects of systems development and integration, from design through procurement, manufacturing and quality assurance and airworthiness accreditation. This rationalization has taken place across all lead firms, increasing with the launch of each successive generation of aircraft. For example, as Embraer moved from the ERJ-145 line to the ERJ-170/190 project, it increased the number of risk-sharing partners from four to 16 and reduced the total number of suppliers from 450 to 40 (Sturgeon et al., 2013); similar changes occurred in the manufacture of the Boeing 787, where the company reduced the total number of companies with which it engaged directly to 50 Tier 1 suppliers (Tang & Zimmerman, 2009); while Airbus reduced the number of suppliers from 250 to 90 as it shifted from the A330 to the A350 successor (Haas, 2011). There is a high degree of interaction and information flow between primes and the Tier 1 suppliers with monthly/bimonthly meetings and shared information systems regarding upcoming orders (Alfalla-Luque et al., 2013). Because it builds trust and aligns incentives, this collaboration can help create the conditions for deep “relational” linkages between business partners (Sturgeon et al., 2013).

As a result of these downward pressures from the lead firms, there has been consolidation at the Tier I level. Requirements to participate in the development of the new planes included minimum revenues; for example, Airbus requires Tier I suppliers to have a minimum of US\$165 million in annual turnover to be considered (Haas, 2011). Other changes suppliers were forced to undertake included hiring of customer managers and contract specialists, quality assurance and training teams, as well as the creation and expansion of engineering departments (Haas, 2011). They must also establish a constant improvement plan and ongoing performance evaluation of sub-contractors. As a result, the new supply chain structure required firms to be strong financially, technically and managerially, and many firms were forced to merge with larger players or drop to Tier 2 or 3 status (Haas, 2011; C. Rose-Anderssen et al., 2011; Sturgeon et al., 2013). In this competitive environment, Tier I firms have also sought to gain related capabilities through acquisition of new firms to improve their value propositions vis-à-vis primes (Field Research, 2016). The past ten years have thus been characterized by significant merger and acquisition activity; between 2012 and 2014, for example, 125 deals valued at over US\$50 million took place (PwC, 2015b). UTC, Honeywell and Thales all purchased smaller firms that were struggling with the new requirements (The Economist, 2014). By 2015, the top 50 firms in this segment each grossed more than US\$2 billion annually (PwC, 2014). In some cases, there are now fewer than five suppliers of specific sub-segments and these firms serve all major integrators, including the new challengers COMAC and MHI. For example, three firms dominate jet engines, GE Aviation, Pratt & Whitney (UTC) and Rolls Royce, while airframe manufacturer Spirit, is Boeing's largest airframe supplier, it is also a key supplier airframes for Airbus's A350 (Mecham, 2013b). Table 6 details the leading systems suppliers.

The shift to sole-sourcing contracts through risk-sharing arrangements has occurred at the same time as a significant increase in volume requirements, giving way to the beginning of higher systematization of parts production.

Historically, aircraft manufacturing has been very low volume with suppliers responding to relatively unpredictable orders from integrators for their products. The shift to sole-sourcing contracts now allows them to utilize integrators' order backlogs as a stronger indicator for demand. This lead-time can be as long as eight years of production volume. With more predictable and higher demand, combined with a drive to lower prices, Tier I firms have begun to establish production plants which draw on the lean manufacturing principals of the automotive sector (Champagne et al., 2013; Field Research, 2016), as well as to invest more in developing their supply chains. Some of these companies are shifting from 80-20 make-buy models to 20-80, where 80% of their production is outsourced (Field Research, 2016). This has created opportunities for strong, well-financed new entrants at the Tier 2 level. These suppliers are now under more pressure to respond to these new demands.

Table 6. Top 20 Leading Systems Suppliers (Tier 1), 2014 by Revenue and Systems

Firm	HQs	2014 Revenue (US\$ billions)	2014 Employment (A&D)	Main Systems
United Technologies (incl. P&W)	US	28.7	76,141	Engines
General Electric	US	24	44,000	
Safran	France	15.3	69,000	
Rolls Royce	UK	13.9	39,900	
MTU Aero Engines	Germany	4.72	9,000	
Honeywell (*)	US	15.7	45,000	Diversified
Finmeccanica	Italy	17.8	47,000	Airframes
Mitsubishi Heavy Industries	Japan	4.41	81,845 ^a	
Spirit Aerosystems	US	6.8	16,000	
Triumph	US	3.9	13,828	
Orbital ATK	US	3.2	12,000	
Kawasaki Heavy Industries	Japan	2.34	35,471 ^a	
GKN	UK	3.43	12,350	
Thales	France	6.05	17,951	Avionics & Electronics
Cobham	UK	2.96	10,941	
L-3 Communications	US	10.9	38,000 ^a	Communications equipment
Rockwell Collins	US	5	20,000 ^a	
Harris	US	3.6	23,000 ^a	
Zodiac	France	5.08	30,000	Aircraft Interiors
BE Aerospace*	US	2.6	9,617	
Parker Hannifin	US	2.3	54,754 ^a	Motion control and flow

Source: Authors based on PwC (2014) and company annual reports.

Notes: (*) denotes presence in the Philippines. Exchange rates are referenced for December 31, 2014 from www.xe.com; Euro (US\$1.21), Pound (US\$1.56), Yen (US\$0.00835). ^a Includes all firm employees.

Consolidation is thus also taking place at the lower tier stages of production to support these expanding demands. The pressure to reduce costs while increasing production rates and providing more “near finished and finished components” has also led to changes amongst Tier 2, 3 and 4 suppliers (Michaels, 2013). These suppliers are expected to double production at lower prices, while also being required to finance tooling that was previously underwritten by the principal contractors. In addition, although many of the components at these stages of production are modularized/standardized, and destined to a large number of industries (e.g. fasteners), the materials specifications together with the airworthiness certification that now falls with suppliers can increase the costs of production of serving the aerospace sector (Field Research, 2016). Many SMEs simply cannot afford to do this (Deloitte, 2015). Notably, there has been an upswing of acquisitions of Tier 2 and 3 firms by Tier 4 firms seeking to expand their operations and ‘add value’ to their raw materials supply (PwC, 2015b). For example, Precision Castparts Corporation acquired 15 Tier 2 and 3 firms between 2011 and 2014 alone, increasing their employee base by over 12,000 to almost 30,000 and becoming one of the top two global suppliers of nickel alloy, rotating-grade titanium, investment castings, forgings, fasteners and large structural castings (Aeroweb, 2015b; Michaels, 2013).

Today, as a result of all of these changes, there are fewer, larger firms at different nodes, challenging the lead firms with respect to margins, operations and information flows. Large Tier 1 firms, particularly in the airframe and engines segments, are in a strong position to negotiate vis-à-vis primes earning margins over 10%, while the surviving parts-making Tier 2 firms have strengthened their margins to 17% (see Table 7). Indeed, the top three most profitable companies in the sector in 2013 were parts and components providers, TransDigm, Meggitt and Precision Castparts Corp (Deloitte, 2015b; PwC, 2014). As composite and specialized materials are increasingly incorporated in the design of new aircraft, the power of specialized raw materials suppliers is likely to rise in the face of scarce resources, technological sophistication and their acquisition of the weaker Tier 3 suppliers. The shift in R&D ownership also means that Tier 1 firms can now sell their products to the new integrators in China and Russia (Crane et al., 2014). Boeing has sought to reverse this loss of power by bringing some design functions back in-house. For example, for the upcoming 737 MAX, design on the nacelles was carried out by Boeing (Mecham, 2013a). These industry dynamics are thus likely to continue to evolve in the near future.

Table 7. Aerospace Industry Operating Margins and Revenues, 2010-2014

	Revenues (US\$ billions)					Operating Margins (%)				
	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014
Primes	334.5	335.0	362.1	365.6	371.6	7.6	7.9	7.5	8.2	8.4
Engine	-	-	65.0	64.8	67.8	-	-	12.3	14.7	14.4
Airframes	25.6	28.1	28.7	30.7	31.8	4.7	5.1	4.5	5.5	7.9
Electronics	73.8*	72.0*	93.7	87.2	86.7	10.6	6.5	12.2	10.6	11.2
Other Tier 1	135.2	142.1	39.4	40.5	43.7	11.6	12.7	12.3	12.4	13.3
Tier 2	32.7	36.3	35.7	30.9	32.8	14.3	14.2	12.4	17.2	17.2
Tier 3	4.0	5.1	2.9	2.8	2.9	11.6	12.3	7.7	3.6	6.9
Services		62.7	54.4	46.9	44.9	13.6	7.0	7.5	7.0	5.3

Source: Deloitte (2011, 2012, 2013, 2014, 2015b)

Note: *Defense electronics only; Prior to 2012, Deloitte included engines and commercial electronics under Tier 1. These were separated into distinct categories in 2012.

Box 3. Lead Firms in the MRO Services Segment

Airlines, third-party providers and equipment manufacturers all compete in this lucrative segment. Large airlines such as Air France, Iberia and Lufthansa Technik are key leaders, leveraging in-house competencies for profit generation by offering their services to other airlines, while many smaller and low-cost airlines have preferred to outsource this capital-intensive function to third-party providers to keep costs at a minimum. In the past, third-party providers often operated under license agreements with equipment manufacturers to maintain and repair components and sub-assemblies. However, in the 1990s, these manufacturers entered the segment as part of a shift towards a full-service business model. Driven initially by engine manufacturers using strategies such as limited access to technical manuals, parts and tooling, thus making services certifications more difficult to obtain, these firms have increased their participation in this after-market. Original equipment manufacturers offer their clients important value propositions including predictable costs, a single source for all maintenance and expertise that airlines or third-party operators cannot easily maintain on their own.

Source: Bamber and Gereffi (2013a).

2.4 Global Regulatory Environment in the Aerospace GVC

With increased outsourcing, a growing number of safety-critical components and parts have been moved to suppliers. Due to the potentially fatal consequences of production errors in the aircraft manufacturing industry, quality standards have been implemented broadly across the sector, from standards for aircraft design through specific standards that apply to different materials used in the production of aircraft. Aviation authorities in respective countries, such as the US Federal Aviation Agency (FAA) and the European Aviation Safety Agency (EASA), determine these standards (De Florio, 2006). In order to meet these high safety standards, while meeting increased production rates, the aircraft manufacturing sector has developed a robust certification process throughout the chain.

The aerospace sector has been proactive in harmonizing these standards. Today, there are two main global standard and certification processes that govern all manufacturing and distribution segments of the value chain: AS9100 family and NADCAP.

- AS9100 was developed in the 1990s by the International Aerospace Quality Group (IAQG), comprised of leading aerospace companies in the US, Europe and Asia with the intention of establishing a single quality management system for use within the aerospace industry (Vasconcellos et al., 2007). AS9100 takes the ISO 9001 requirements and supplements them with additional quality system requirements, which are established by the aerospace industry in order to satisfy the US Department of Defense, NASA, FAA and EASA quality requirements. While the AS9100 standard is recognized worldwide, participating countries can use their own numbering conventions. Revisions occur at regular intervals to maintain its applicability and correspondence with ISO 9001, with the most recent revision C released in 2004. The AS9100 family of standards includes AS9110 and AS9120 which are specific to the MRO and distribution stages of the chain to ensure services and chain of custody of genuine parts (see Table 8). IAQG hosts the Online Aerospace Supplier Information System (OASIS) database with supplier and audit assessment data for all companies who hold an accredited certification in any of the Aerospace Quality Management Systems series of Standards.
- NADCAP (National Aerospace and Defense Contractors Accreditation Program) standards establish industry-wide audit criteria for specialized processes and products specific to the industry, such as heat treatment, welding, chemical processing and non-destructive testing (PRI, 2015). Auditing is carried out by the Performance Review Institute, established by industry primes and Tier 1s, in an effort to eliminate redundant additional audit processes that each of these firms were carrying out with their suppliers (Inagaki et al., 2014). NADCAP certifications are only required for firms serving US supply chains, although they are valued by most firms which serve both the US and EU markets.

These standards cover quality management systems, risk management, process verification, product quality and testing amongst others. Important financial commitments are often required

to achieve adequate safety and quality levels that can serve as barriers to entry for smaller manufacturers in the absence of access to finance (Haas, 2011). These certifications are typically time-consuming and costly for businesses, particularly smaller operations, to obtain as they require not only the addition of qualified technical expertise at a firm, but they also often require restructuring of firms' management systems to integrate the quality management operations, systems tracking and performance review process. For example, in order to develop adequate tracking to ensure traceability of certified steels for machining, a firm may be required to invest in Enterprise Resource Planning software, using barcodes for all materials and products developed in the operation (Field Research, 2016). Although each subsidiary must be individually certified, MNCs tend to have an advantage over their SME counterparts as they are often better prepared to obtain certifications as their operations must follow strict global protocols.

Although small suppliers continue to face challenges to meet these standards, harmonization has simplified the process and helped to reduce the overall cost and complexity for suppliers. Today, the majority of primes and Tier 1s require AS9100 certification as a prerequisite for contracts at all levels of the supply chain, while specific processes must be NADCAP certified. Airbus and Boeing require Tier 1s to cascade these requirements to their sub-tier suppliers. Just 20 years after its creation, it already extended to cover 80% of direct and indirect suppliers (Haas, 2011). Once a supplier has registered its certifications in the IAQG's OASIS and NADCAP databases, this is recognized globally by the majority of firms in the industry. This reduces the burden of contract negotiations and auditing. In addition, industry experts highlight that it has been a very successful in increasing risk management through out the chain (Diesing, 2014).

In addition to AS9100 and NADCAP standards, MRO specific activities must also meet industry specific standards to ensure that ongoing maintenance and repair complies with high quality operations of the supply chain and ensure airworthiness. The most widely recognized standard is the FAA 145 certification for repair stations. Table 8 summarizes the key standards required by leading regulatory agencies around the world.

In addition to the private standards highlighted above, two further sets of public standards also apply to the aerospace manufacturing sector regulating safety and security. Safety standards are managed on a national level by national aviation authorities. The airworthiness of all components and sub-assemblies used in civilian aircraft must be certified by these organizations. For example, in the original manufacturing process, home agencies of the primes/ integrators (e.g. Boeing, Bombardier) must certify the airworthiness of products, while in the after-market segment, the home agencies of the buyers (e.g. airlines, lessors, etc.) must certify products.

Numerous bilateral air safety agreements have been signed between agencies such as the US and Mexico in 2007, and the US and Singapore in 2004 covering the issue of airworthiness between these countries (FAA, 2016a).

Table 8. Standards in the Aerospace Manufacturing Global Value Chain

Standard	Country	VC Segment	Description
AS9100	Global (Specific numbers by countries)	Manufacturers	AS9100 takes the ISO 9001 requirements and supplements them with additional quality system requirements, specific to the aerospace industry. The intent of AS9100 is to establish a single quality management system for use within the aerospace industry. Primes require Tier 1s to cascade these requirements to their sub-tier suppliers (Haas, 2011).
AS 9120	Global	Distributors	This standard addresses chain of custody, traceability, control and availability of records. AS9120 is applicable for organizations that resell, distribute and warehouse parts found in aircraft and other aerospace components. The standard is not applicable to value-added distributors due to customer-product changes nor is it intended for organizations that rework or repair products.
AS9110	Global	MROs	The AS9110 aerospace standard is based on AS9100, but adds specific requirements that are critical for the maintenance of commercial, private and military aircrafts. This standard defines the quality system requirements based on AS9100 and includes additional criteria for MRO facilities serving the aircraft industry.
FAA 145	US/International	MROS/ repair stations	The FAA Type 145 repair certificate authorizes facilities to perform maintenance and airframe/engine repairs on specific aircraft. The FAA uses the Type 145 certification process to determine if a repair station has the equipment, personnel, manufacturers' maintenance instructions and inspection systems to ensure aircraft repairs are completed to US aviation standards.
DO-178B, DO-178C, DO-254/ Eurocae ED-80	United States	Avionics Developers	DO-178B/C is primarily concerned with development processes. The targeted DO-178B/C certification level is either A, B, C, D or E. Correspondingly, these DO-178B/C levels describe the consequences of a potential failure of the software: catastrophic, hazardous-severe, major, minor or no-effect. The RTCA DO-254/Eurocae ED-80 document provides guidance for design assurance of airborne electronic hardware from conception through initial certification and subsequent post-certification product improvements to ensure continued airworthiness.

Source: Authors, based on De Florio (2006), FAA (2016b) and SAE International (2012).

Due to the dual-use nature of both products and technologies in the commercial and defense aerospace sectors, there are significant security regulations managing the diffusion of these products and technologies. Internationally, these are managed under the **Wassenaar Arrangement**. In 2015, there were 41 participating members of this arrangement, including both traditional aerospace manufacturing hubs (US, UK, Europe, Japan) as well as newcomers (Mexico, Poland, South Korea, South Africa, Turkey and the Ukraine) (Wassenaar Arrangement Secretariat, 2016). Requirements for participation cover both national proliferation policies as well as the adherence to fully effective export controls. With weaker institutions, developing countries often face challenges in meeting export control requirements. Not participating in this arrangement can complicate access to the necessary technologies to upgrade operations and precludes access to some of the leading defense markets in the world. As many aerospace companies operate in both the civilian and defense sectors simultaneously, this can limit their decisions to invest in certain locations.

2.5 Human Capital and Workforce Development

Quality and safety assurances for the industry depend on well-trained personnel, and the attraction, development and retention of human capital significantly influences opportunities to grow in the sector (LARA, 2001). Competencies and capabilities are thus central to competitiveness of firms in different tiers of the aerospace industry (Cooke & Ehret, 2009; Hickie, 2006), and are a core part of industrial policy, spearheading sector growth in developed and developing countries alike.

Overall, the industry depends heavily on skilled workers—in particular engineers, technicians and skilled production workers (Lloyd, 1999). At manufacturing companies, employers seek out workers with robust advanced manufacturing skills and experience, such as welding, drafting and assembly (Haas, 2011).¹⁵ Certification requirements are greater at MRO companies because their contracts with air carriers often stipulate that workers carrying out MRO work hold specific certifications.

Strong growth, supply chain restructuring and the introduction of new technologies, combined with an aging global workforce have impacted the role of workforce development within the aerospace industry.

First, there has been a change in the overall employee profile throughout the chain. The restructuring of the value chain has shifted a wide range of activities from the aircraft manufacturer to its supply base around the world. These new activities require a broad range of capabilities from design and development, to customer relationship management, finance and procurement and quality assurance (Haas, 2011). New technologies have also increased the role of avionics engineers. This has created increased demand for high skilled service professionals in the value chain.

Second, the rationalization/consolidation of the supply base requires a multifunctional workforce to help meet just-in-time requirements of lean manufacturing. Ongoing performance improvement system is now a basic criterion for a supplier's inclusion in the chain. This has raised requirements for ongoing formal and informal training of workers (Haas, 2011).

Third, there is a growing need to increase the quantity of this qualified human capital available globally as the industry prepares for significant retirement. It is estimated that some 24% of the manufacturing workforce and 18% of aerospace engineers globally will retire by 2020. Combined with projected growth in the industry, there is a global need for a large number of workers for the aerospace sector. It is estimated that approximately 450,000 technicians, and 12,500 engineers must be added to the workforce over the next decade, globally (Murray, 2014; PWC, 2015a). However, companies are increasingly concerned about being able to recruit qualified workers. There has been an overall decline in interest in Science, Technology, Engineering and Mathematics (STEM) activities, while universities and technical schools are generally disconnected from the needs of the industry.

Table 9 shows the profile of employees in the aerospace manufacturing sector.

¹⁵ These certifications are mainly used to advance to more senior positions (RTI, 2009).

Table 9. Key Employee Profiles in the Aerospace Manufacturing Sector

Broad Employee Profile	Positions	Principal Formal Education Attainment & Training Requirements	Experience
Administration & Management	Customer relationship & services manager Procurement specialists Contract specialists Quality managers Training managers Financial analysts Recruitment specialists	Mostly bachelor degrees. Some masters degrees, such as Master in Business Administration	Industry and lean-manufacturing experience preferable
Engineers	Aerospace Electrical Industrial Materials Mechanical Software Systems	Mostly associate and bachelor degrees. Some masters & doctoral degrees	Firms require two to four years of experience from either aerospace or another advanced manufacturing facility.
Technicians	Drafters & designers Electrical Electronic Machinists (Metalworking & plastic molding) Mechanics Quality & process Tool and die makers Non-destructive testing	Associate degrees or trade school training. Apprenticeships and specialized on-the-job (OJT) training. FAA certification in some positions: Airframe mechanic, avionics repair specialist and power plant mechanic.	
Assemblers	Assemblers Sheet metal workers Composite fabricators First line supervisors	Mostly high school graduates. Apprenticeship and OJT	Firms may occasionally waive experience requirements.

Source: Authors based on Haas (2011); PRISM (2012); RTI (2009).

2.6 Upgrading Trajectories in the Aerospace GVC

Upgrading in the aerospace industry has been heavily influenced by government policy and financial support seeking to engage in aircraft manufacturing for reasons of self-reliance, national security and pride and technology transfer (Eriksson & Steenhuis, 2016). Countries that have upgraded in the industry have sought a number of different approaches to doing so, each of which involves a series of discrete upgrading trajectories. These have included attempts to enter the value chain by 'leap-frogging' into systems integration (e.g., Brazil and China) as well as gradual development of capabilities through manufacturing (e.g., Mexico, Malaysia and Singapore), or as pure MRO service providers (e.g., El Salvador) (Bamber & Gereffi, 2013a). The few developing countries in the sector (with the exception of Brazil and China) have followed the approach of entering into components or assembly stages of the value chain, after which they have functionally upgraded into higher stages of the chain in engineering and/or design

works of sub-assemblies. Table 10 highlights select upgrading trajectories of developing countries in the aerospace GVC.

Table 10. Select Upgrading Trajectories in the Aerospace GVC

	Upgrading Trajectory	Description	Examples
Value Chain Entry	Into product assembly and/or component production	• Assembly of parts based on imported components or manufacture of simple components. Firms typically initiate operations in a new location with a small number of product parts.	• Philippines
	Into MRO Service Provision	• Provision of MRO services for the industry; most countries develop these skills providing mandatory and basic MRO operations for domestic flights, before beginning to offer a wider range of services for a broader market.	• Malaysia, Singapore • El Salvador
Functional	To engineering and design for sub-assemblies	• Engineering and design of parts for major sub-systems, based on gradual build up in competencies in the manufacture of parts and components.	• Singapore
Market	To after-market (e.g. MRO providers)	• Sell spare parts to the after-market MRO service providers. In this market, the same part can earn 2-3 times that of the original supply chain. This often requires process upgrading to respond to the need for speed to market.	• Malaysia
Product	Product Upgrading:	• Move from the production of simple to more complex, higher value components. This can occur within aircraft systems (e.g. interiors, airframes or propulsion) or by moving into new systems production entirely. As a location increases capabilities, firms often begin to increase the total number of product parts produced.	• Mexico
Process	Process Upgrading:	• Improve production systems to increase productivity; obtaining AS9100 certification requires significant process upgrading, in terms of continuous process improvement, and implementing quality management systems. Other examples include installing new generation CNC machines that are significantly more energy efficient.	• All countries

Source: Authors.

I. Entry into value chain in product assembly or component production:

Assembly of parts based on imported components or manufacture of simple components. Firms typically initiate operations in a new location with a small number of product parts. This is often followed by functional upgrading into the manufacture of components. In addition to undertaking component manufacturing processes, moving into this stage of the chain may require developing capabilities in procurement functions in order to purchase raw materials if these are not supplied by the buyer.

2. **Functional upgrading from components and assembly to design for sub-assemblies:** This encompasses developing capabilities in the engineering and design of parts for major sub-systems, based on gradual build up in competencies in the manufacture of parts and components. Singapore entered the propulsion systems segment with firms such as Hamilton Sundstrand and Rolls Royce (RR) producing parts for engines. By 2012, RR was assembling and testing the Trent 900 and Trent 1000 engines in Singapore (Francis, 2015), accounted for 15% of the country's aerospace exports and had opened an R&D center in the country.
3. **Market Upgrading: Moving from supplying the Manufacturing Chain to the After-Market** Strong MRO growth globally has driven demand for replacement parts for planes. These parts require low volumes, but rapid turnaround times, as the length of MRO operations is minimized to keep planes in service. In this market, the same part can earn 2-3 times that of the original supply chain. This often requires process upgrading to respond to the need for speed to market such as in the development of logistics and distribution capabilities.
4. **Entry and upgrading in MRO Service Provision:** This involves the development of MRO operations to service aircraft and sub-systems, this can occur independently or in parallel with manufacturing capabilities upgrading. The single most important driver of the MRO segment is air transportation, with regional fleet size and projected growth providing strong indicators for demand. Geographic consideration and airport infrastructure is crucial. MROs need to have major facilities in key traffic flow areas, as it is expensive to fly planes long distances for maintenance requiring just a few man-hours. At the same time, nonetheless, leveraging low-cost locations, skilled labor and quality performance for non-geographically sensitive work such as component MRO and more intensive maintenance work, is also important for sustaining competitiveness in the long term. Two Asia-Pacific examples include Malaysia and Singapore. These countries have built their initial MRO capabilities serving their flagship carriers, such as Malaysia Airline and Singapore Airlines. Of the two, Singapore is the largest and most successful, with 56 FAA Part 145 Certified repair stations compared to 15 in Malaysia and estimates suggest that Singapore controls between 20 and 25% of the Asia Pacific MRO market (Economic Development Board - Singapore, 2015; US Commercial Services, 2012).
5. **Process Upgrading:** This entails improving production systems to increase productivity, such as obtaining AS9100 certification. This certification requires significant process upgrading, in terms of continuous process improvement, and implementing quality management systems to ensure any particular life threatening failures in production are averted. Over the past ten years, AS9100 has become a standard industry requirement leading to widespread uptake in the industry in developed and developing economies alike. For example, by 2015, 58% of aerospace firms in Mexico were certified. Malaysia was much slower to process upgrade, with just 26%. Other examples include installing new generation CNC machines that are significantly more energy efficient, and developing a range of other

process capabilities such as heat treatment and non-destructive testing.

6. **Product Upgrading:** This covers shifting from the production of simple to more complex, higher value components. This can occur within aircraft systems (e.g. interiors, airframes or propulsion) or by moving into new systems production entirely. In Mexico, for example, initial capabilities were developed in a wide range of basic component in metals and plastics in Baja California – many of which were used in Interiors systems. The country has undergone significant expansion in the number and value of products that it produces. Today, these include higher value composite versions of earlier products, as well as airframe structures and engine components.

3. Lessons for Upgrading from Malaysia and Mexico

In order to help define the potential upgrading of the Philippines in the aerospace sector, the upgrading experiences of two of these developing countries, Mexico and Malaysia, are examined. These two cases were selected, as they are both reasonably recent entrants that have been able to maintain and grow their involvement in the sector. Growth in both countries has been driven by active industrial policy programs, illustrating the importance of specific instruments such as the development of human capital for the sector.

The two countries, nonetheless, illustrate different strategies for growth. While Mexico offers an example of exclusively export-led growth with a number of clusters focused on different systems within the industry, Malaysia provides an example of a mixed model, using domestic demand and offsets in combination with domestic investments in composite technology to develop the industry. Foreign direct investment (FDI), nonetheless, has played an important role in both countries reflective of tight supplier driven chains in the industry. Importantly, despite the success in product and process upgrading in both countries, neither country has undertaken significant upgrading into higher level design and development stages of the chain, illustrating the difficulties of doing so in this industry and the reluctance of lead firms to offshore these activities.

3.1 Mexico

Mexico's growth in the aerospace sector has been dramatic; exports have increased approximately 20% per annum for the past 15 years and the country had become the 15th largest exporting country, by value, in the industry by 2015 (see Table 3). Although Honeywell and Westinghouse have been manufacturing basic components in the country since the 1970s (Carrillo & Hualde, 2011; EY, 2014), work in the aerospace sector really began in the mid-1990s, when GE established a large engineering operation in Queretaro. Mexico led global investments in aerospace between 2001 and 2011 and by 2014, there were 289 companies operating primarily manufacturing facilities in the country. By 2014, the combined workforce of

the industry was approximately 45-50,000¹⁶ and the country had reached US\$3.3 billion in manufacturing exports. Furthermore, activities were no longer confined to lower value manufacturing, but now included more sophisticated products, sub-assemblies as well as some engineering. Service exports account for some 20-25% of total industry exports (EY, 2014).

The country is strongly engaged in the North American regional production network. The majority of investment is from the US (41%) and Canada (40%), although 80% of firms by number are of U.S. origin. Canadian investments are buoyed by the presence of Bombardier, which has invested US\$550 million in its Queretaro plant for the manufacture of fuselages its Learjet 85 and the Global 7000 and 8000 jets (Secretaria de Relaciones Exteriores (Mexico), 2013). Export destinations are almost entirely focused on the US and Canada, which continue to account for over 85% of exports. This consolidation of exports is declining slightly with France becoming an increasingly important partner, thanks mostly to increased European investments in recent years.

Three states dominate the sector to date: Baja California, Queretaro and Chihuahua, drawing 12.5%, 48% and 11.2% of sector investments, respectively, between 1999 and 2014 (PWC, 2015a). A proactive industry development policy articulated in the 2007 and 2014 National Flight Plans, as well as *Pro-Aerea 2012-2020* has focused on establishing ways in which the different aerospace clusters across the country can work together to develop alternatives for the entire value chain, including highlighting niche areas for development in different clusters.

- **Baja California:** Baja California is the region with the longest trajectory in the industry; early movers such as Rockwell Collins and Honeywell have been in the state for over three decades. Baja's entry into the aerospace sector has been driven primarily by its proximity to the US and the availability of large number of low-cost, qualified workers.¹⁷ By 2014, with 80 firms, approximately 28,000 employees and US\$1.4 billion in exports, it was also the most significant contributor to the aerospace sector in the country (Baja California Aerospace Cluster, 2016). Like many of their peers in the region in other sectors, these mostly foreign aerospace firms have mainly concentrated on metal-mechanics, plastics and electronics operations and are Tier 3 and Tier 4 operations.¹⁸ Firms have responded to the requirements of the industry by becoming certified, with 71% and 30% certified in AS9100 and NADCAP respectively by 2014 (Baja California Aerospace Cluster, 2016). In addition, they have adapted to the changing technologies of the industry with a vast number of components now being manufactured from composite materials. Despite this progress, the region's long trajectory and an explicit goal to become an offshore R&D center for fuselage systems and power plants, most firms have not been able to functionally upgrade.¹⁹ While there are exceptions, such as Honeywell's Mexicali Research and Technology Center which

¹⁶ References vary on the exact number of employees in the sector; however, just six of the large MNCs (Airbus Helicopters, Bombardier, GE Aviation, Honeywell, Safran and Zodiac Aerospace) employed some 22,250 people between them.

¹⁷ Indeed some 30% of the manufacturing firms operating in the region pre-date the NAFTA agreement (Carrillo & Hualde, 2007).

¹⁸ Firms based in Mexico also cater to the military market, with 63% of production dedicated to combined civil and military aviation projects (Carrillo & Hualde, 2011).

¹⁹ However, BC has diversified its products for a number of different sub-assembly segments (Romero, 2010).

performs full scale simulations of different aircraft, there is a strong indication that lead firms have leveraged Baja California's close proximity to the US to access low-cost component manufacturing and assembly labor for in-house, non-critical, non-core functions (Romero, 2010).

- **Queretaro:** Queretaro's development was anchored by GE Aviation and Bombardier, which established operations in 1994 and 2006, respectively. The French group Safran and Spanish airframe manufacturer, Aernnova, quickly followed suit, establishing operations in 2007. Queretaro's aerospace cluster has since become one of the three leading locations in Mexico, accounting for one-sixth of the country's aerospace exports. The state has developed capabilities in airframes, engines and MRO operations, and its long-term strategy is focused on precision-machining capabilities along with continued MRO services. By 2014, there were 34 firms operating in the state, with projected employment of over 6,000, approximately 20% of the country's aerospace workforce. The state was a strong choice for locating an aerospace cluster thanks to its large engineering base and strategic location on the Pan-American highway between Mexico City and the US border, and the development of relevant infrastructure. In 2009, engineering graduates accounted for 41% of undergraduate degrees, while 65% of master's degree programs available in the state were in engineering fields.
- **Chihuahua:** Like Baja California, Chihuahua has benefitted from its proximity to the US and the Maquiladora regime²⁰ with strong manufacturing experience in the automotive and electronics sectors. It is also considered one of the lowest-cost locations in the country for aerospace, attracting labor-intensive product segments such as wire harnesses (ProMexico, 2012). The state graduates some 4,500 engineers and technicians for the sector per year. Chihuahua's participation in the aerospace sector centers around prime integrators from Textron – Cessna, Bell Helicopters and Beechcraft, as well as Honeywell and some 30 additional foreign suppliers, including Safran and Zodiac Aerospace. With approximately 13,000 employees, the state accounts for some 11% of Mexico's total aerospace exports (ProMexico, 2012). The state has developed capabilities in landing gear and fuselage operations, in addition to other Tier 3 & 4 components such as wire harnesses, and other metal and composite parts.

Policy Actions

While Mexico is an attractive destination for the sector as a result of its macroeconomic stability, proximity to the US, large, low-cost labor force, and experience in the automotive and electronics sector, the success of Mexico's upgrading in the sector has been a combination of national level investment, trade and air sector policies and state level initiatives, particularly with respect to coordination amongst key actors, education and infrastructure.

²⁰ This Industria Manufacturera, Maquiladora y de Servicios de Exportación (IMMEX) legislation established a special tax regime, referred to generally as the 'maquila' or 'maquiladora' regime, for foreign investors to operate assembly factories in Mexico for export to the US. This regime abolished all tariffs on imported components intended for re-export as assembled products.

At the national level, **trade and investment benefits** under the maquiladora (IMMEX) regime and free trade agreements with key partners in the industry (US, EU and Japan), and the abolishment of all tariffs on imported components for the aerospace sector via the drawback mechanism and streamlined customs processes for the sector²¹ cut the costs of manufacturing components and sub-assemblies in the country. In addition to lowering taxes, NAFTA has been a crucial driver for overall growth in two key areas: logistics and human capital. Investments in road, rail, sea and air **infrastructure** and services to support the growing maquila sector have increased volumes and reduced transit time for products across the US. Products can be shipped to any US destination by road in five days and air in five hours. This has helped connect the industry in a just-in-time model to key aerospace plants in the US and Canada. Strong experience developed in the automotive and electronics sectors – key beneficiaries of NAFTA – has supplied a base of human capital and education systems to support the growth of advanced manufacturing in aerospace.

Table 11. Overview of Key Aerospace Manufacturing Clusters in Mexico

	2014 Exports (US\$, million)	% Mexico Exports	No. of Firms	Employees	Manufacturing Capabilities	Long-term Vision	Major Companies
Mexico	3,200	100%	289	45-50,000	Airframes, Engines, Electrical and electronic systems, landing gear, composite materials components manufacturing, MRO	Top ten global aerospace supplier & destination that supports complete aircraft life cycle from design to part manufacturing & assembly, MRO, and recycling at end-of-life	3 Primes (e.g. Cessna, Bell, Bombardier partial assemblies) Multiple engine tier 1 & 2 – (e.g. GE & Goodrich) 2 airframe tier 1 (e.g. Aeronnova, SAFRAN)
Baja California	1,400	28%	80	28,000	Precision machining, metal plate conformation, electrical and hydraulic systems, complete integration testing	KPO leader for fuselage and power systems	Honeywell, Goodrich (UTC), Gulfstream, Rockwell Collins Lockheed Martin
Queretaro	675	13%	34	6,000	Propulsion systems, airframe structures, sub-assemblies and subsystems, engine components, landing gear systems	Hub for complex machining processes and MRO	Bombardier, Safran, Airbus Helicopter, Galnik, General Electric
Chihuahua	570/750	11%	32	13,000	Electrical systems for aircraft, helicopter	Final assembly of a full aircraft and an MRO	Textron (Bell Helicopters,

²¹ Tariff classification 9806.00.06 was created to provide tariff benefits for imports of inputs for the aeronautics sector in Mexico to increase its competitiveness. That tariff classification allows tariff-free imports for assembly or manufacture of aircraft or aircraft parts, as well as for goods intended for the repair or maintenance of aircraft or aircraft parts, benefitting MRO activities.

					structures and assemblies, metal components, engine components	center for single aisle planes	Beechcraft and Cessna), Honeywell, Zodiac Aerospace
--	--	--	--	--	--	--------------------------------	---

Source: Adapted from EY (2014).

Specific aerospace policies have also played a fundamental role, and the most important of these include:

- the 2007 national bilateral aviation safety agreement (BASA) with the US²² and agreements with 40 other countries,
- improvements to the intellectual property regulatory framework and the establishment of export controls for conventional arms and dual-use products leading to the 2011 acceptance into the Wassenaar Arrangement, and the possibility to use offset agreements to obtain technological skills,
- the 2006 establishment of the Mexican aerospace industry association, FEMIA (*Federación Mexicana de la Industria Aeroespacial*), instrumental in establishing the national industry strategy,
- the promotion of five clusters centered on the 'triple helix' model of bringing together key industry stakeholders.

Domestic sector growth has been partly driven by the high demand for business jets in the country, which is the second-largest global market after the US and firms eager to tap into the country's defense budget. The government has translated this market-seeking into growth through offset agreements which brought Eurocopter (Airbus Helicopters) to establish a plant in Querataro with 200 employees to manufacture emergency exit doors and tail booms for Eurocopter. Full domestic assembly of the Ecureuil is expected by 2017.

²² In 2005, a small number of components and systems qualified for domestic certification, such as landing gear components and audiovisual equipment. The 2007 agreement significantly extended this list of products to cover the majority of goods produced in Mexico (Carrillo & Hualde, 2007).

Table 12. Federal Policies Supporting Aerospace Growth in Mexico

Date	Policy	Description	Implication for Sector
1967	IMMEX and Drawback	Regulation of assembly operation for a Mexican manufacturer that is wholly owned by a foreign parent. The drawback allows for tax-reimbursements of tariffs on imported raw materials and components.	<ul style="list-style-type: none"> Temporarily import goods and services that will be manufactured, transformed or repaired, and then re-exported without payment of taxes, compensatory quotas and other specific benefits
1994-ongoing	NAFTA, Free Trade Agreements (45 countries including EU (2000) and Japan (2005)).	Free trade agreements facilitate flows of components and sub-assemblies between countries	<ul style="list-style-type: none"> Reduce overall production costs Transportation costs lower as a result of increased volumes of trade
2007	Bilateral Air Safety Agreement signed with the US & 40 other countries	DGAC Mexico can certify airworthiness of components, sub-assemblies and assemblies manufactured, assembled or repaired in the country for use in the US & other signatory countries.	<ul style="list-style-type: none"> Reduction of regulatory burden Components can be assembled directly without international certification
2007	Establishment of 5 Aerospace Clusters & Promotion of Triple Helix Approach	5 states were singled out for their existing performance in the industry to establish state level strategies which included formally coordinated relationships between local government, educational and research organizations and the private sector.	<ul style="list-style-type: none"> Allowed for regional collaboration instead of competition Coordination of actors ensured that industry needs were being met
2011	Wassenaar Arrangement Evaluation & Acceptance	Export controls and regulation of information are evaluated with respect to whether the country is a reliable destination for sensitive technologies	<ul style="list-style-type: none"> Country can participate in the manufacture and sale of products for the defense industry
	Intellectual Property Protection	The country has developed a strong legal infrastructure for protecting intellectual property rights. The Mexican Institute of Industrial Property is responsible for the enforcement of all industrial and intellectual property laws in Mexico	<ul style="list-style-type: none"> Together with Wassenaar membership and the establishment of an export controls, this has allowed firms to serve the lucrative defense market, not just in the US but other countries
2006; 2011	National Flight Plan Strategy 2012-2020	National development strategies for the aerospace sector	<ul style="list-style-type: none"> Set out specific goals and deadlines for the country's engagement in the industry
2010	Offset Agreement with Airbus Helicopters	Under the 2010 contract for the Mexican Airforce and Navy, Airbus committed to manufacturing certain components and sub-assemblies in Mexico. Agreement also requires plant to be managed by Mexican staff by 2017.	<ul style="list-style-type: none"> US\$100 million investment in emergency door production and tail-boom assembly facility in Queretaro US\$550 million future investment planned to allow for full assembly of helicopters Facilitation of knowledge transfer to local management

Source: Authors.

State-specific Programs: Most programs to drive upgrading at the state level have been focused on improving human capital and infrastructure.

Baja California: Human capital initiatives have helped forge close relationships between the industry and educational and research bodies. For example,

- In 2010, Autonomous University of Baja California (*Universidad Autónoma de Baja California, UABC*) opened the Aerospace Technology and Engineering Center and an engineering campus with a world-class laboratory specializing in composite materials, built in collaboration with Honeywell Aerospace.
- The National College of Professional Technical Education established a precision engineering center partially sponsored by Zodiac Aerospace and Solar Turbines, which engaged both in terms of equipment installation and curriculum development. This has helped to ensure training complies with AS9100 standards.
- Ceyts University has established both undergraduate and graduate programs in aviation engineering, while Tijuana University of Technology (*Universidad Tecnológica de Tijuana, UTT*) has a mechatronics engineering program and two professional technical programs in mechatronics and the manufacture of aerospace harnesses, which were adapted to the needs of the local industry.

As the region has sought to upgrade, the establishment of the Baja California cluster, along with industry-specific incentives under the 2005 Competitiveness and Economic Development Law helped to develop a strategic roadmap with short, medium, and long-term goals for the sector.

Queretaro: The National Aeronautics University of Queretaro (UNAQ) was established in 2007, which housed several technical programs developed in public-private initiatives and created the first aerospace engineering program in the country. State investments in UNAQ amounted to US\$21 million by 2009. In addition to training teaching staff in both Canada and Spain, UNAQ draws teachers from aerospace firms working in the region. By 2012, there were 488 technical and professional students at UNAQ. UNAQ's contributions to human capital development in the state added to an already strong engineering training base. In addition, a US\$11.5 million industrial park was established adjacent to the newly constructed Queretaro International Airport in 2004.

Chihuahua: Three programs have been important for driving industry growth:

- the 1995 establishment of the Center for Advanced Materials and its current evaluation for NADCAP certification,
- significant investments in engineering education and,
- a memorandum of understanding with the US DOD, allowing the production and use of sensitive technologies and dual-use products for the lucrative US defense market.

In addition to its continued pursuit to bring higher value activities and products to the country, Mexico's next big challenge will be to engage locally owned firms in the aerospace chain. With the majority of firms foreign owned, it is difficult to capture the value of its production locally.

3.2 Malaysia

In 2014, Malaysia's aerospace industry generated US\$1.1 billion in manufacturing export revenue (see Table 21) and overall, with US\$1.8 billion in MRO exports (Fuzli Fuad, 2014), recorded a 14% growth rate. Successful upgrading to this position was achieved in less than two decades. Although the aerospace industry in Malaysia was founded in the 1970s with the establishment of Aircraft Inspection, Repair and Overhaul Depot (AIROD), AIROD's privatization in 1985, and later, launch of the first National Aerospace Industry Blueprint in 1997, marked the beginning of the rise for a dynamic aerospace industry in the country (MIGHT, 2015; Tat, 2005). Malaysia has since rapidly built capabilities in MRO operations and also in parts manufacturing and assembly. Over the last decade, Malaysia managed to attract investment by some of the leading Tier 1 firms in the aerospace industry. The aerospace industry in 2014 employed 19,500 people and encompassed 159 foreign and domestic companies, including 62 firms directly invested in key segments of the aerospace value chain: eight parts assembly companies, 20 manufacturers of aircraft parts, and 34 firms in MRO activities (MIDA, 2014a). Whereas MRO still dominates the industry, the aerospace manufacturing industry has shown dynamic export growth since 2005, with sub-assembly exports growing approximately three-fold by 2014.

Development: Since the establishment of Malaysia's modern aerospace industry in the 1990s, public-private partnerships and investment in niche technological capabilities have constituted the core upgrading strategy and driver to entry into aerospace GVC. The establishment of Composite Technology Research Malaysia (CTRM) in the early 1990s, was the first major breakthrough into composite material technology and the introduction of aircraft manufacturing such as Eagle-XTS all composite, and later Lancair (Tat, 2005). Taking the impetus from this early success, the first industry blueprint was launched in 1997, underlying public-private collaboration and charted the long-term strategic direction for the industry. In less than a decade after its establishment, CTRM entered into multiple contracts to supply Airbus composite wing components for A320 series and A380 aircraft by early 2000s (Tat, 2005). CTRM in Malaysia is now the fifth largest global supplier of composite structures, supplying integrators such as Airbus (MIGHT, 2015). In addition to CTRM, in early 2000s, Aerospace Composite Malaysia, a strategic alliance between Malaysian companies, Sime Darby and Naluri, and its US partners, Boeing and Hexcel Corporation, was established to locally manufacture composite structures for Boeing commercial aircraft (Tat, 2005).

Later in the decade, other major aerospace engine and parts manufacturers have established industrial footprint in Malaysia, including Honeywell and Spirit Aerostructures in 2009. With these developments, Malaysia's aerospace manufacturing acquired capabilities in composites, metallic, and assemblies, elevating the country to a regional hub of choice for Tier 1s (Boeing, 2005; MIGHT, 2015).

Policy Support

Policy interventions have created an innovative industry ecosystem to drive competitiveness and upgrading in Malaysia, which has faced stiff competition from the established regional player, Singapore, but also emerging markets such as Vietnam and Thailand. Policy initiatives formulated at the national level focused on investment, trade, workforce development,

infrastructure development and also creation of public-private platforms that identified upgrading opportunities in the aerospace GVC and spearheaded coordinated response involving industry, government and education institutions.

Trade and Investment: Since 2003, Malaysia has offered a comprehensive trade and investment incentive package for the aerospace industry. These policy incentives target the entire value chain, spanning the design, manufacturing and assembling, operator group, and MRO services. Allowing 100% foreign ownership, the incentive package has offered income tax exemption of 100% for a period of five to 15 years; investment tax allowance of 60%; and, double deduction on expenses incurred by employers providing training (MIDA, 2014b). Further, aerospace companies undertaking MRO activities qualified for import duty and sales tax exemption on raw materials, components, machinery and equipment, spares and consumables. Complementing these generous incentives, the Malaysian Investment Development Authority (MIDA) has pursued aggressive promotion activities worldwide. It has managed a worldwide network of 24 overseas offices across the world, concentrating in the major global aerospace hubs in North America, Europe and Asia Pacific (MIDA, 2014b). In addition, the government also introduced **offset programs** to drive its exports and technology transfer in the industry. These included two engines offsets arrangements for procurement of new A330 and A380 planes by Malaysia Airlines. The Trent 900 program for the A380s was launched in 2006, and in 2015, formally adopted an offset policy for national procurement valued over US\$12 million in 2015 for high technology industries (MIGHT, 2016). That same year, as a follow-on from the Trent program, Rolls-Royce announced a joint venture in the country as the company's regional establishment for engine parts manufacturing (Bloomberg Business, 2015).

Development of Domestic Firms: Investment incentives, exclusively targeting Malaysian-owned businesses, also included grant support that focused on driving upgrading and entry for local firms. In 2012, the Domestic Investment Strategic Fund was established for the purpose. Malaysian-owned businesses have been awarded matching (1:1) grants related to technology acquisition, R&D, and compliance with international standards (MIDA, 2014b). Broadly, the program has focused to build local firm capabilities so they can capture upgrading opportunities offered by the outsourcing activities of MNCs.

Sector Strategy & Institutionalization: In the mid-1990s, the Malaysia Industry-Government Group for High Technology (MIGHT) was established as an industry-driven non-profit organization charged as the leading agency to bring together industry stakeholders, government and academia. The objective has been to ensure upgrading progress through consensus and technology development and acquisition by the aerospace industry in Malaysia. Although this group has successfully created a stakeholder platform, realization of upgrading objectives were certainly hinged on decision making at the highest level. The latter was ensured by establishing Malaysian Aerospace Council in 2001 (MIGHT, 2015). Chaired by the Prime Minister, with membership from the six relevant ministries, aerospace industry representatives, and MIGHT as the secretariat, this council constituted a national level steering body that systematically charted policy priorities and implementation strategies for upgrading.

These policy initiatives successfully created a pathway through which private sector could contribute in demand-driven R&D. The Aerospace Malaysia Innovation Centre, since its

incorporation in 2011, has emerged as a key industry-led innovation center, involving lead global firms, and local technology leader, CTRM (AMIC, 2015). As a pioneer center in the region, the center has focused on substantially improving the commercial success of aerospace R&D with pre-project clarity on technology recipients from the industry and a well-defined route to market.

Human Capital Development: MIGHT's linkages with the industry also facilitated development of education and training programs in tandem with the industry upgrading strategies. Established in 2002, a consortium of 11 public universities in Malaysia (MMAM, 2015) has focused on addressing human capital needs of aerospace and other high-technology related industries. This national initiative established the foundation for more specific targeted alliances with firms to address skill gaps in niche areas.

The LEADER²³ Aerospace Program, for instance, has been established as a partnership with primes and their Tier 1 suppliers, whose contribution includes allowance for trainees, utilization of the prime technical specialists and training facilities in Malaysia and overseas (Advance Manufacturing Institute, 2015). Today, Malaysia's human capital development infrastructure for the aerospace industry is comprised of 66 education and training providers that deliver bachelor degrees and diploma programs covering a wide range specialties including aerospace, aeronautical, maintenance technology, avionics and composite repair, and aircraft flight and cabin crew (MIGHT, 2015). Annually, these institutions graduate 300 engineers and over 2,000 technicians that not only supply local talent to Malaysia's industry but are also exported to neighboring countries as well as the EU and the US (MIGHT, 2015).

Infrastructure: The Asian Aerospace City project, located in Selangor, 20 km west of the Kuala Lumpur city center, has illustrated a major policy commitment to expand the underlying infrastructure for the aerospace industry. Under the Economic Transformation Program of the Malaysian Government, the aerospace city initiative, worth US\$1.1 billion is expected to be completed by 2018 (Economic Transformation Programme, 2015; Rakwan, 2015). Aimed at attracting the largest global Tier 1s, the city is intended to create a competitive hub for industrial talent, cost efficiency, and connectivity among Malaysia's aerospace industry stakeholders.

23 LEADER stands for, "Leadership in Design Expertise through OEM driven Apprenticeship for Aerospace."

4. The Philippines and the Aerospace Global Value Chain

The Philippines is a newcomer to the global aerospace manufacturing industry. The country's entry into the GVC has been based on the establishment of key anchor firms in the country. These firms have mainly been attracted to the large qualified pool of workers in the Philippines. Although the country has been host to a Tier 1 flight controls manufacturer, Moog Controls Corporation, since 1985, the industry only began to expand within the past five to ten years. The installation of three additional Tier 1 providers in the Interiors and Electronics segments, together with increased global demand for Moog's products during this period, has provided impetus for growth. In addition, the global rise of outsourcing by Tier 1s has helped several small and medium sized local suppliers enter the sector as Tier 2 or 3 suppliers. While the total number of firms in the sector is low – only 10 firms registered exports over US\$500,000 in 2014 – exports have accelerated in recent years, from almost negligible exports in 2010 to US\$604 million in 2014. This has helped create 3,000 full time jobs, with an additional 3,000 part time workers also supporting the industry and contributed 1% of the country's total exports.²⁴

Sector growth to date has been largely organic. As a result, firms cover various different product segments, and are situated in different locations in the country. Firms have established aerospace operations in three systems segments, Electronics, Interiors and Flight Controls and primarily carry out the components manufacturing and assembly segments of the chain. Geographically, these firms are dispersed; they are located mostly in EPZs in Luzon, to the North and South of Manila – in Baguio, Clark, Subic and the Batangas area.

Although still a relatively new industry and a very small player with manufacturing exports accounting for less than 0.15% of the global industry, recent growth of the industry is promising. Both foreign firms that have established operations in the country and the local suppliers that have entered the industry have already achieved some degree of upgrading within a short period of time. These include expanding the product lines served, obtaining essential process certifications and advancing beyond basic assembly operations to undertake additional manufacturing processes such as machining and begin to perform procurement and engineering functions in country. This section examines how the industry has evolved and upgraded to date and where in the value chain the country is currently positioned. A final section discusses the Philippines in comparison with the two previous case study countries, Mexico and Malaysia, drawing on their experience to highlight key lessons for growth.

4.1 The Philippine Entry into the Aerospace Global Value Chain

The development of the aerospace manufacturing sector can be divided into two distinct stages: (1) Early and slow development between 1985 and 2008, during which time Moog, mostly in isolation, expanded its product lines and capabilities with sporadic engagement of local suppliers, while the government engaged in two short-lived production programs – the Defiant and the Hummingbird – for the air force (AIAP, 2013); followed by (2) the more recent expansion between 2008 and 2015, which has involved a larger subset of firms and corresponds to a period of strong growth in the global industry. As the goal of the research is to position

²⁴ This is based on a total of US\$62.1 billion in goods exports in 2014 reported in the PSA firm-level data.

the country moving forward, this analysis will focus on this latter period. As highlighted in Table 13, this latter period marks the establishment of a small number of large foreign Tier 1 and 2 suppliers to the commercial aviation segment in the country, as well as the entry of local automotive and/or electronics suppliers to service the industry.

Table 13. Overview of Leading Firms in the Philippine Aerospace Industry, by Entry Year

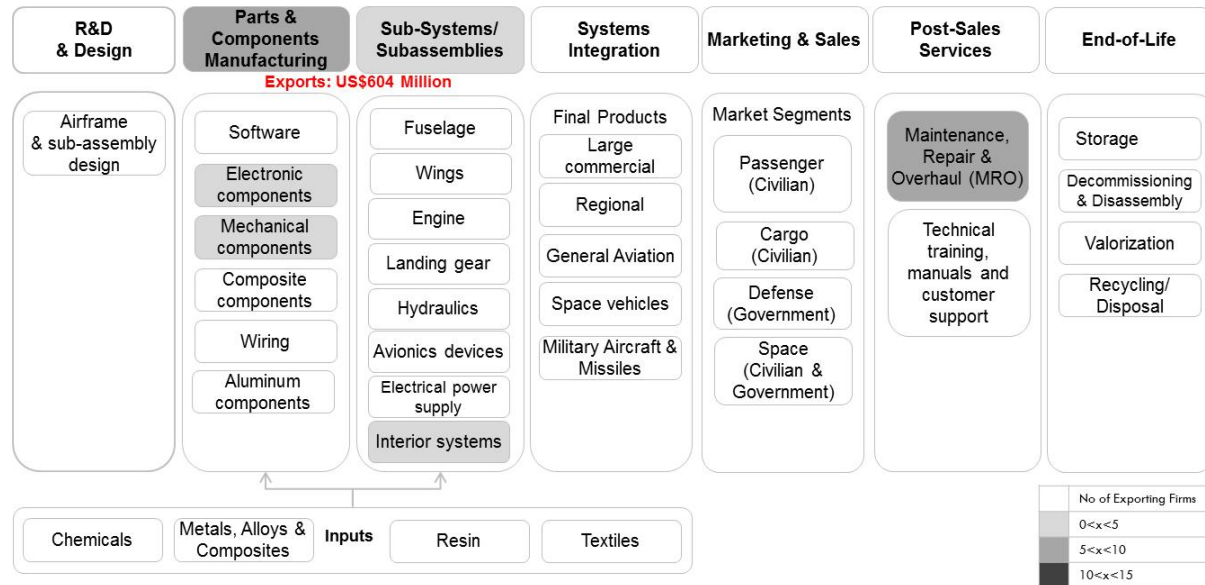
	Firm	Origin	Entry Year	Tier	Activities & Systems Focus	AS 9100	Location
Stage 1	Moog Controls Corp	US	1985 (Exp. 2005)	1 & 2	Flight Controls: Components & Assembly. Servo actuators for leading and trail edge of wings	2009	Baguio
Stage 2	Famous Secret	Philippines	2008	3	Final Craft: Assembly 4 seaters Interiors & Airframe: components machining	2014	Cavite
	Dornier Technology ²⁵	Germany/ Philippines	2008	Prime	MRO Final Craft: Assembly of two-seat sea planes in general aviation.	NA	Clark
	DJ Aerospace	US	2009	3	Machining & Forming & Heat-Treatment of components	2009	Subic Bay
	Surface Technology International	British/ Spanish	2009	1 & 2	Electronics systems: Manufacture and Supply of Printed Circuit Board and Box Build Assemblies	2013	Cebu
	Applied Machining Corporation	Philippines	2010	3	Machining	2010	Laguna
	Microsemi Semiconductors	US	2010	2 & 3	Components & Assembly	2011	
	B/E Aerospace	US	2011	1	Interiors: Components & Assembly. Galleys, Galley Inserts & Lavatories	2012	Laguna
	JAMCO	Japan	2011	1	Interiors: Components & Assembly. Galley Panels, Floor Panels	2015	Clark
	Aurochs Aerospace Precision Manufacturing	Philippines	2012	3	Machining metal components for servo actuators	NA	Baguio
	MD Aerospace Fabrication	Chinese	2013	3	Fabrication of aerospace parts	NA	Laguna
	CC Barleta Machine Service Center	Philippines	2014	3	Machining, Fuel & Hydraulic Systems	2015	Laguna

Source: Authors based on company websites, Field Research (2016); International Aerospace Quality Group (2016) and PEZA (2015).

²⁵ Dornier Technology's facilities in the Philippines are dedicated to manufacturing sea planes to suit the country's air-traffic needs. Any operations they have in the Philippines are not AS9100 certified.

Figure 4 highlights the Philippine entry into aerospace GVC to date. No shading indicates no participation in the sector. Grey shading indicates there is at least one or more firm operating in the industry.

Figure 4. Philippine Participation in the Aerospace Global Value Chain



Source: Authors.

Note: The grey scale represents the number of firms in the country in each stage with over US\$500, 000 in exports in 2014.

These firms have been primarily focused on components manufacturing and assembly. The Tier I firms are mainly production centers of global firms, which have engaged smaller local suppliers as they have sought to outsource more of their manufacturing operations (Field Research, 2016). Foreign firms tend to be larger than their local counterparts – the largest two firms each have over 1,000 employees, and, although globally they attend more than one industry, they primarily serve the aerospace sector from their Philippine operations. Generally, local firms carry out machining and some finishing operations for components for the anchor firms, although they are beginning to develop some capabilities in direct exports. There are no input suppliers in the country for the sector, as the Philippines does not produce any of the sophisticated raw materials required by the industry and low volumes to date have limited the establishment of a local distributor.

The role of the anchor firms in driving growth is reflected in the evolution of the Philippine product exports. The leading aerospace exports for much of the past two decades have been

focused on flight control systems, including servo valves and servo actuators.²⁶ Since 2008, the product range exported has become more varied as new firms have entered the industry, with some consolidation in the production of components and sub-assemblies for interiors systems. Interiors products include machined seat parts, galley inserts (e.g. coffee makers, ovens, etc.), galley structures and lavatories for a range of commercial jets, although these are mostly the high-selling models of Airbus (A320, A350) and Boeing (737, 787) which justify large scale industrial operations. One firm, Famous Secret Precision Machining (FSPMI), also assembles light sport aircraft kits for export. Product lines for the 787 and the A350, which entered into production in recent years, were brand new global production sites for the firms in the sector. Other products for older models including the 737 and the A320 were transferred from existing production plants in other parts of the world, and the US and the UK in particular. The rapid increase in production of these models by Airbus and Boeing required a considerable increase in global capacity for components and sub-assemblies for these planes and the Philippines provided a competitive low-cost alternative. Table 14 provides an overview of the main products being exported, using the narrow definition of the industry used in the global trade analysis. Based on this assessment, total aerospace exports reached just US\$250 million in 2014.

Table 14. Philippine Aerospace Exports, by Value Chain Segment or Product Category, 2014

	Export Value (US\$ millions)			Systems	Products
	2010	2012	2014		
Components & Sub-Assemblies	5.5	128.9	249.4	Avionics	Electronic components
				Interiors	Seat parts
					Galley inserts
					Galley structures
					Lavatories
				Flight Controls	Servo actuators
					Servo valves
Final Products	-	-	5.5	Final Aircraft	Assembled sport planes
Total	5.5	128.9	254.9		

Source: Authors based on Firm Interviews, UN Comtrade, HS02 6D codes, Reporters exports to the World, Retrieved 10/29/15 and Firm-Level Data.

Using firm-level data for the Philippines, however, allows for a slightly more nuanced analysis of the country's participation in the components and sub-assemblies segments, and highlights that the strict definition of exports underestimates the size of the industry participation. As noted before many of these products can be destined for a range of other sectors, including the automotive, electronics and household appliances, and as global trade statistics do not

²⁶ These include hydraulic or electrohydraulic actuators and include hi-lift and gear-type actuators. They come in various sizes and the largest one can weigh up to 200 pounds. ²⁶ For a single Boeing 787, Moog supplies over 200 separate servo actuators (APEC Policy Support Unit, 2015).

differentiate between end-market uses, comparative cross-country data cannot be used. Table 15 thus provides a more detailed breakdown of exports by product category based on the top ten firm exports.²⁷ In addition to exports that are specifically categorized as aerospace exports (PSCI-2004 categories 84 and 88), the top ten leading firms also export a range of electrical and electronic components (PSCI-2004 85) which account for 20% of the total of those firms. Using these more precise statistics, it can be estimated that the Philippines is exporting approximately US\$604 million in products destined for the aerospace sector, or 1% of the country's total exports.

Table 15. Leading Exports of Top Ten Aerospace Exporters, 2014

Description	PSCI 2004 Category	2014 (US\$ millions)	Share of Exports
	Total	604.1	100%
Nuclear reactors, boilers, machinery, etc.	84	237.7	39%
Reaction engines other than turbo-jets and parts	8412	105.9	18%
Shafts, cranks, gears, clutches, flywheel, pulleys etc.	8483	74.2	12%
Taps, cocks, valves and similar appliances, and parts	8481	53.5	9%
Aircraft, spacecraft, and parts thereof	88	193.8	32%
Parts of aircraft, spacecraft, etc.	8803	180.7	30%
Aircraft launching gear, flight simulators	8805	7.4	1%
Final aircraft	8802	5.5	1%
Electrical, electronic equipment	85	116.1	19%
Electric motors and generators, except generating sets	8511	97.4	16%
Radar, radio navigation and remote control apparatus	8526	7.1	1%
Electrical machinery and apparatus, nes	8543	3.2	1%
Rubber and articles thereof	40	8.3	1%
Tyres nes, retreaded, used pneumatic, solid, cushioned	4012	6.2	1%
Pneumatic tyres new of rubber for aircraft	4011	2.3	0%
Optical, photo, technical, medical, etc apparatus	90	5.3	1%
Navigational instruments, direction finding compasses	9014	3.7	1%
Automatic regulating or controlling equipment	9032	0.8	0%
Parts, accessories nes for opto-electric instruments	9033	0.4	0%
Aluminium and articles thereof	76	1.8	0%
Articles of aluminium nes	7616	1.7	0%
Articles of iron or steel	73	1.1	0%
Articles of iron or steel nes	7326	0.7	0%
Screws, bolts, nuts, rivets, washers, etc., iron, steel	7318	0.4	0%
Sub-Total		564.2	93%
Others		39.9	7%

Source: Philippines NSO (2013).

Note: Leading aerospace exporters identified, based on total exports registered in HS2D 88 or 84 product categories. Exports in product categories HS86 and 87 were excluded from the total as these products are

²⁷ While there may be some remaining degree of error in the estimation, as some aerospace suppliers continue to serve the automotive and electronics industry, this is a far closer approximation.

explicitly categorized as automotive or railway products. 'Nes' refers to the UN Comtrade specification 'not elsewhere specified'.

End Markets

The industry in the Philippines serves several major aerospace manufacturing hubs, and exports have been increasingly destined for the US and EU as the new Tier I firms ship assembled products to both aircraft integration sites and their global hubs. Firms in the industry report serving a wide range of customers at the prime and Tier I level, including Airbus, Boeing, Embraer, Goodrich, Liebherr and MHI amongst others (Estoque, 2015; Field Research, 2016). Nonetheless, there are some regional ties with 19% of exports destined for Japan, China, Malaysia and Singapore in 2014. Most firms sell directly into the primary manufacturing sector (i.e. plane assembly), however, at least one firm, Moog, has already begun to sell into the more lucrative after-market (Estoque, 2015). This market segment demands one off pieces with rapid response times (usually 24 hours), which requires manufacturers to hold inventories of either raw materials or product numbers as well as manage efficient production operations.

Table 16. Philippines Top 5-10 Export Destinations, 2014

Destination	Value (US\$ millions)				Share of World Aerospace Exports (%)			
	2007	2010	2012	2014	2007	2010	2012	2014
World	297.9	5.5	128.9	254.9	100%	100%	100%	100%
US	36.0	3.4	16.2	72.2	12%	62%	13%	28%
Netherlands	15.4	0.0	1.0	65.7	5%	0.1%	1%	26%
Switzerland	1.8	0.0	21.1	20.4	1%	0%	16%	8%
Japan	5.1	0.3	2.8	17.2	2%	5%	2%	7%
China	0.9	0.0	20.4	15.0	0.3%	1%	16%	6%
UK	8.3	0.5	7.9	13.0	3%	9%	6%	5%
Malaysia	1.2	0.1	4.9	9.0	0%	1%	4%	4%
Spain	0.1	0.0	0.0	7.8	0%	0%	0%	3%
France	12.0	0.0	1.4	6.6	4%	0%	1%	3%
Singapore	32.3	0.0	12.2	6.0	11%	1%	9%	2%
Top 10	113.1	4.3	87.8	232.9	38%	78%	68%	92%

Source: UN Comtrade, HS02 6D codes, Reporters exports to the World, Retrieved 10/29/15

The Emerging MRO Sector in the Philippines

In addition to entering the aerospace manufacturing, the Philippines has an emerging MRO sector, with 8 FAA certified repair stations.²⁸ These include major regional and global players such as Honeywell, Lufthansa Technik (LT) and Singapore Airlines Engineering (SIA). These firms have tended to cluster around the two airfields in Luzon: Metro Manila and Clark. Total employment in the sector in 2014 was approximately 2,600 people, although the largest firm,

²⁸ One of these stations, certified in December 2015, Airworthy Aerospace Industries has no employees as of yet (FAA, 2016b).

LT, accounts for the majority of these employees. These firms continue to serve the local rather than export market – including Philippines Airlines, Cebu Pacific and the Philippines Airforce and have capabilities related to the commercial, general aviation and defense segments. However, both LT and SIA have undertaken an expansion of their hangars and training of new technicians in order to accommodate more wide body planes, including the A350, A380, 777 and 787 for heavy maintenance with the goal to serve the growing regional market (Lufthansa Technik, 2015). SIA's new operations are the firm's only foreign operations for heavy maintenance work (SIA Engineering, 2016).

Table 17. MRO Operators in the Philippines, 2014

Firm	Country of Origin	Year Established	AS 9100	FAA 145 Repair Station	Total Employees	Location
Philippines Aerospace Development Corporation (PADC)	Philippines	1973	--	No	NA	Manila
Lufthansa Technik	Germany	2000	--	Yes	2,291	Manila
Fieldtech Asia	Philippines			Yes	11	Manila
Asian Aerospace Corporation	Philippines	1996	--	No		Clark, Cebu
Metrojet	Philippines			Yes	15	Clark
Moog Controls Corp	US			Yes	60	Baguio
Nordisk Aviation Services				Yes	7	Clark
Honeywell	US	2003	2009	Yes	22	Subic
Dornier Technology	Germany/ Philippines	2008	--	No	NA	Clark
Assistance Aeronautique & Aerospatiale	France	2012	2013	No	NA	Clark
SIA Engineering	Singapore	2012	--	Yes	196	Clark

Source: Authors based on company websites, FAA (2016b).

4.2 Early Upgrading in the Aerospace Sector

Although the country's engagement in the industry is relatively recent, important strides have already been made in expanding local capabilities at the functional, process and product level. This has occurred at both the foreign and local firms.

- **Functional:** While the work being undertaken is primarily in the components manufacturing and assembly segments of the chain, the engineering talent in the country, many of whom have worked in the automotive manufacturing sector, is skilled in terms of interpreting engineering designs and developing manufacturing engineering plans. This has facilitated the expansion of the operations in the country from following detailed engineering instructions provided from headquarters to locally producing production plans and programming machinery (Field Research, 2016). In addition, a handful of local suppliers, which initially began working with locally based Tier 1's, are now beginning to work with

additional buyers via direct exports. This market expansion has required local firms to upgrade their capabilities in not only marketing and sales functions, but also in procurement operations, forecasting and financial management to manage inventory risk of raw materials.

- **Process & Product:** At the product level, All Tier 1s have at least doubled their production operations since opening, and have expanded beyond their first product line that they were established to produce and, as a result, supplier firms have also expanded their product numbers. This product upgrading has been facilitated by the development of additional processing capabilities, and machining, sandblasting, buffing, painting, and anodizing processes are all carried out locally. Supplier firms have invested heavily in new CNC machines dedicated exclusively to their production for the aerospace sector. In addition, to meet the requirements of global firms, since 2009, nine manufacturing firms have achieved their AS9100 certifications (Table 13),²⁹ including several local suppliers such as, FSPMI and AMC which obtained their certifications in 2014 and 2015 respectively (International Aerospace Quality Group, 2016).

This upgrading has required a major shift of operations for at least three supplier firms, which previously served the automotive industry. The automotive sector is based on a high volume, low mix production operation, and orders could include half a million pieces for less than ten product parts, with low regulatory control. Comparatively, when serving the aerospace sector, this model shifted to some 1,000 product numbers with ten pieces per unit, under high regulatory control. In particular, this upgrading of capabilities required contracting of large numbers of engineers as well as experienced personnel from abroad, upgrading of enterprise resource planning systems and software to improve traceability, such as the implementation of barcoding of inventory, as well as establishing quality management and performance improvement systems in line with the market demands. This upgrading required significant financial investments.

Box 4. Upgrading Success - Moog Controls Corporations

Moog Controls Corporations is the oldest aerospace firm in the country, having established operations near Texas Instruments in Baguio in 1985. The firm began operations with just 24 employees – mostly engineers manufacturing two simple components. MOOG further expanded its production operations in 2005, and has slowly upgraded in all categories—product, process, functional, and chain. Today, the company has 1,300 full time employees, fabricates and services over 2,000 distinct components and smaller sub-assemblies for aerospace flight controls systems and sits on a sprawling 7.2ha campus. The Philippines has also become the firm's key manufacturing hub across its global production network, producing directly for Airbus, Boeing, Bombardier and Embraer, but also for Tier 1s such as Liebherr and Goodrich. The facility's products can be found in all the new plane families – the 787, A380 and A350. The site began by following all instructions from abroad, but quickly ramped up to machine programming, and then to sustaining engineering and now production engineering. The Philippines operations provide supply chain management support for production, and is engaged in developing local suppliers. In addition to directly serving the manufacturing market, the firm also works in the highly competitive and demanding MRO segment, and is an FAA Certified 145 Repair Station for the

components and sub-assemblies that it manufactures. Finally, Moog has managed to retain its human capital as it has grown, providing considerable upward mobility for workers. The average age of employees is 10 years higher than that in the remainder of the industry, and many workers have been with the company since they graduated from university.

Sources: APEC Policy Support Unit (2015); Estoque (2015).

4.3 The Philippine Aerospace Workforce

There are approximately 3,000 full time employees working in the aerospace sector in the Philippines. An additional estimated 3,000 employees work in supplier operations that also serve the automotive, electronics and industrial sectors (Field Research, 2016). The education and experience profile of this workforce is mostly skilled and semi-skilled, with a heavy reliance on engineering graduates (specifically, electronics, electrical, and mechanical engineering). Of these employees, all have a minimum of high school plus some technical education, and just under half are qualified engineers. Generally speaking, the more complex and critical the products being manufactured by firms, the higher the percentage of engineers in their workforce. The industry also provides important opportunities for female workers, with men and women each comprising approximately half the workforce (Field Research, 2016).

Industry members noted that workers are typically provided full time contracts, due to the significant training required for their participation in the sector. Due to the low volume, high mix production model, employees need to perform multiple functions such as operating multiple tools, machines, understanding materials' characteristics and following detailed schematics, amongst others. As a result, developing employees can be very costly. Nonetheless, the strong sense of loyalty of the Filipino contributes to low attrition rates; most firms report attrition rates of just 2-4% (Field Research, 2016).

Firms in the sector mostly recruit directly from university or technical programs, although they also draw on experienced employees from the automotive sector and MRO operations. There is less overlap with the electronics sector, as those operations tend to be more highly automated than the aerospace sector, where the work is considerably more labor-intensive. Although no firms reported recruiting aerospace engineers, there are several schools in the country offering 5-year Bachelor of Science programs in aerospace engineering and aviation electronics technology (CHED, 2016b). Technical programs include CNC Machining training, as well as aircraft maintenance through the Philippines TESDA institutions, such as the ATM Aircraft Training Center (Philstar, 2009). There is a very heavy emphasis on on-the-job training (OJT); it can take a machinist between 3-5 years to reach expert-level. This OJT is available both to students, at the technical institutions, students are required to complete an internship in industry prior to graduation, and then this is complemented by ongoing training at work. Knowledge transfer is facilitated by personnel exchanges between incumbent plants and Philippines subsidiaries, as well as between Tier I firms in the country and their local suppliers.

4.4 Advantages and Challenges for GVC Participation and Upgrading

The recent entry of the Philippines into the aerospace industry has been mainly organically driven, leveraging the country's large qualified, English-speaking human capital pool, competitive export processing zone (EPZ) incentives and the existing manufacturing capabilities developed serving the regional and global automotive and electronics industries. These advantages have provided an important foundation. Nonetheless, certain efforts need to be made to overcome a number of key constraints to industry upgrading, including filling essential supply chain gaps, improving the regulatory environment for the aerospace sector – particularly with respect to bilateral and multilateral agreements on safety and export controls and alleviating challenges in

logistics and energy infrastructure and services. This section discusses these key strengths and weaknesses for growth.

Table 18. The Philippines in the Aerospace GVC 'SWOT' Analysis

Strengths	Weaknesses
<ul style="list-style-type: none"> • Available, English-speaking, cheap engineering talent • Good industrial relations • Efficient and competitive EPZ regime • Experience in the automotive and electronics industries 	<ul style="list-style-type: none"> • Supply chain gaps – raw materials availability and key processes • Poor infrastructure & related services • High energy costs • No bilateral safety agreements • No participation in Wassenaar Arrangement
Opportunities	Threats
<ul style="list-style-type: none"> • Strong growth and demand for products in the aerospace sector –existing shops are maxed out. • Increased product opportunities in interiors & flight controls, electrical systems • More and improved manufacturing processes • Increased engineering opportunities 	<ul style="list-style-type: none"> • Uncertainty regarding political stability with six year governments • Competition from strong aerospace locations in Malaysia and Singapore as well as upcoming Vietnam and Thailand • Government subsidies in competitor countries

Source: Authors.

4.4.1 Advantages

Available, English-speaking, and cost-effective engineering talent with a strong work ethic: The available supply of cheap, yet qualified English-speaking engineers in the country has been a major factor for firms in the aerospace sector to invest in the country (Field Research, 2016). Local universities graduate approximately 60,000 engineers annually in mechanical, electrical & electronic, and chemical engineering (CHED, 2016a). These degree lines are well suited to the product manufacturing operations located in the country. There has also been a growing focus on aerospace engineering specifically; the number of students passing the Aerospace Engineers Board examination in the Philippines has tripled from just 51 in 2011 to 165 in 2015 (Professional Regulation Commission (Philippines), 2016). Language provides the Philippines with a distinct advantage over other low cost players, including Malaysia, Mexico, Thailand and Vietnam where English is not widely spoken. Given the problem-solving and relational nature of the industry, language barriers can undermine potential for upgrading.

Finally, the 'ladderized approach' to education through the implementation of the Philippine Qualifications Framework, which permits students to temporarily exit the education system, facilitates a supply of technical staff and for constant upgrading of employees skills. For example, TESDA offers technical machining courses to students dropping out of the competitive engineering programs, allowing three year engineers to complete additional short term technical training (APEC Policy Support Unit, 2015). This approach to skills upgrading offers firms in the Philippines a strong basis for ongoing economic upgrading and increases retention of the workforce which is key in the industry's development. Attrition rates in the Philippines

are considerably lower than in neighboring countries; in Malaysia, attrition rates have been as high as 25% in recent years (Min & Kumar, 2012).

Export Processing Zones and the Philippines Economic Zones Authority

(PEZA): Industry in general, in the Philippines, faces important challenges with respect to bureaucracy, corruption and inefficiency (The World Bank, 2016). The EPZs and PEZA, however, have helped to alleviate a good deal of these challenges, providing streamlined import and export procedures, as well as a competitive tax and tariff structure and similar regulations regarding ownership and repatriation of profits to many other new emerging players in the industry, including Mexico and Malaysia (Field Research, 2016; Manasan, 2013a). As the majority of aerospace products manufactured in the country are destined for export, these firms qualify for PEZA registration. PEZA is recognized both domestically and in the region for its efficiency and efficacy in supporting export-oriented operations (Field Research, 2016; Manasan, 2013a). Although there are no dedicated industrial parks for aerospace manufacturing in the country, there are a large number of EPZs and land outside of Manila is relatively cheap and available for investors to establish operations (Field Research, 2016; Manasan, 2013b).

Experience in the automotive and electronics industries: While significant upgrades are required to move from these industries into the aerospace sector, they provide two important baseline advantages: (1) personnel with experience working in MNCs driven by lean manufacturing principles, and (2) a supply base with CNC machining capabilities. Although the country has not developed exports in these sectors to the extent of its peers in the ASEAN region, such as Malaysia and Thailand, both sectors have operated manufacturing facilities in the country for over 20 years. The recent downturn in the automotive sector has provided human capital, and several companies mentioned they had hired professionals from this sector. Indeed, one firm highlighted that the lean manufacturing skills brought to their workforce by former automotive sector employees had helped to improve existing procedures as product lines have been transferred from abroad. SEIPI, the industry association for the electronics industry, is also one of the most active and well-organized industry associations in the country. Aerospace firms such as Moog have been members of this organization.

Preferential Access to EU Market: The Philippines has been eligible for GSP (and now GSP+) benefits for some time which means its aerospace exports to the EU are subject to zero tariffs (Delegation of the European Union to the Philippines, 2015). However, changes to the GSP system in recent years have given the country a slight competitive advantage over other regional actors in the sector.³⁰ India and the Philippines are the only GSP or GSP+ countries that operate in the aerospace sector in any significant way.³¹ Furthermore, regional competitors, Malaysia and Thailand, lost their benefits in 2013, as they were upgraded to middle-income status (European Commission, 2015b). While this advantage may be short-lived as they are currently in negotiations for FTAs with the EU which could provide them with preferential access,³² it could provide sufficient time for consolidation of the industry in the

³⁰ Including the extension of GSP program from 3 year-periods to 10 year periods. The advantage is slight, given that the tariffs for MFN are not particularly high – ranging between 1.7% and 2.7%.

³¹ Mexico, as a low cost provider has a FTA with Europe (see Section 3.1).

³² See companion report, The Philippines: Upgrading in Manufacturing Global Value Chains.

Philippines. In the meantime, net imports in aerospace parts from Europe have surged in the past four years; from less than US\$500 million to close to US\$1.5 billion (Delegation of the European Union to the Philippines, 2015), as firms have brought the Philippines into their global production networks.

Collaborative Environment for Industry Policy Development: Over the past five years, there have been strong initiatives to develop a supportive and collaborative environment for industry policy development in the manufacturing sector. This has been driven by a number of programs put in place by the DTI-BOI, which focus on identifying and prioritizing the development of high potential sectors in order to revitalize manufacturing in the country. The collaborative implementation of the Industry Development Program and the Manufacturing Resurgence Program (DTI, 2016b; DTI-BOI, 2014)— between and among the private sector, academe and government agencies has played a central role in coalescing industry stakeholders into a more cohesive group and has clearly helped to establish strong lines of communication between the public and private sectors. This has also included an Industry Roadmapping Program, for which the Aerospace Industries Association of the Philippines (AIAP) drafted a roadmap for the development of the industry.

Furthermore, efforts are underway to improve inter-departmental coordination to ensure that policies can be effectively implemented through the Industry Development Council³³ led by the Secretary of the DTI which is tasked with bringing together working groups at the government level (DTI, 2016a; DTI et al., 2014; Field Research, 2016). Despite this progress, long term planning has yet to be adopted for the aerospace industry.

4.4.2 Challenges

While the factors above have provided an attractive destination for aerospace manufacturing, there are numerous constraints to industry growth. The most important of these include essential supply chain gaps, lack of bilateral and multilateral agreements regarding aviation safety and product security, poor infrastructure and expensive energy costs.

Supply Chain Gaps: There are important gaps in Tiers 2, 3 and 4 of the supply chain in the country.

I. Raw Materials Availability (Tier 4): The aerospace industry is one that is highly regulated, using sophisticated materials that require traceability and certification. The Philippines does not produce any of these materials, and due to the small local industry size, volumes to date have been limited. As a result, no distributor has established operations locally. Each individual firm thus imports their raw materials from abroad; both regionally (e.g. China, Singapore and Taiwan) as well as globally (Canada, Germany, UK and US) (Field Research, 2016). For those suppliers working with the local Tier 1 operations, the customer generally

³³ Established by virtue of Executive Order 380, series of 1996, the IDC was re-convened in April and October 2014, aiming to amend E.O. 380 in order to reflect the new institutional needs of the IDC, as well as respond to current realities and challenges of industry development in the country.

supplies materials. This allows suppliers to access the industry without the significant financial and technical costs of having to procure raw materials. For direct exports, however, firms must finance and procure all of the supplies internally, making this a much more costly and capability driven operation.

2. Limited Supply Base Capabilities (Tier 2 & 3): Local suppliers are only moving into basic machining and processes for the aerospace sector at this stage. More high-end machining operations in multi-axis and precision machining are required (Estoque, 2015; Field Research, 2016). In particular, there are no firms -as of yet- providing NADCAP-certified processes in chemical or heat treatment for the industry or in working with composite materials. This means that products have to either be made in-house at Tier 1s or they have to be shipped to/from the US or other locations for painting, coating, etc. This reduces efficiency and erodes the cost-advantages of operating in the Philippines. Developing these capabilities and passing the certification requirements can be costly given the equipment and systems required. This is often beyond the scope of small and medium sized suppliers in the country – especially since the volumes being generated right now are not sufficient to justify the investment.³⁴ To increase the potential for development, the industry association, AIAP, established in 2012 and which has participation from all Tier 1s in the country, has opened its membership to a large number of potential Tier 3 suppliers for the sector; this should help provide a forum for matching of capabilities and sharing information regarding process needs.

Lack of Regulatory Agreements: Bilateral Aviation Safety Agreements (BASA) and the Wassenaar Arrangement. The Philippines does not have existing bilateral aviation safety agreements in place with major aerospace manufacturing hubs which places it at a disadvantage compared to its regional peers, Malaysia, Singapore and Vietnam. As a result, firms must rely on agencies abroad to certify the airworthiness of their products. This creates considerable delays in the production operations; and is particularly problematic in supporting the after-markets sector which serves a large number of different end-markets (as opposed to the primary manufacturing operations which are based in just a small number of countries). Firms must thus comply with the requirements of multiple different agencies (APEC Policy Support Unit, 2015). Competitors in the industry, including Mexico and Singapore, signed these agreements with the US and the EU in 2007 and 1981 respectively. The Civil Aviation Authority of the Philippines (CAAP) is responsible for improving aviation safety management protocols that are essential foundations for these bilateral agreements. The country has been criticized in the past for failing to meet international standards for aviation safety (IATA, 2015). Philippines airlines were in fact barred from flying into both the US and the EU. Recent changes have improved these operations and the aviation authorities of both the US and the EU

³⁴ At the same time, the growing pressure at each stage of the production chain to reduce costs and lead times while simultaneously increasing volumes has led to some rationalization of supply chains around more capable suppliers and centralized procurement operations whereby suppliers are selected and managed globally rather than at each individual subsidiary site. This limits the continued upgrading of local suppliers by existing and potential Tier 1 suppliers in the country.

subsequently removed the Philippines from their blacklists in 2014 and 2015 respectively (Agcaoli, 2014; European Commission, 2015a; FAA, 2014; Larano, 2014). Efforts are also underway to develop human capital to support these improvements with a new post-graduate program that is scheduled to be offered for the first time in October 2016 (Simeon, 2016), as well as courses between TESDA and DOLE.

In addition to BASAs, the Philippines is not a participating country in the Wassenaar Arrangement which manages dual-use technologies. This limits operations in the country to the commercial and general aviation segments. This can create challenges as much of the equipment used in the manufacturer for commercial operations can also be used in that of weapons systems production. This can complicate the export of sensitive manufacturing technologies to the Philippines (APEC Policy Support Unit, 2015). It also reduces attractiveness versus locations such as Mexico as most firms operate in both the commercial and defense segments and thus would need to set up multiple sites which adds to supply chain complexity. Joining the arrangement requires changes to the export controls in the Philippines. Recently, the country moved towards improving export controls to lay the foundation for entry into the defense segment with the signing of the Strategic Trade Management Act in November 2015, which will create an office – Strategic Trade Management Office - charged with implementing the required changes (Deloitte, 2015c).

Logistics & Infrastructure: The congestion of the principal ports in the country and the lack of diversification of shipping lines to the alternative ports means that companies have to hold higher inventories of required raw materials and use more expensive shipping methods (e.g. air freight) in order to meet customer schedules. Although margins in the aerospace sector can allow for more expensive shipping options, these increase the cost to operations in the country and erode the advantages generated from labor arbitrage. It also makes the country considerably less competitive than locations in Mexico, which can ship products to assembly points in a maximum of five days. Furthermore, the separation of the administration of the ports (under the Department of Public Works and Highways, DPWH) and road infrastructure development and management (under the Department of Transportation and Communication, DOTC) in the Philippines contributes to slow implementation of the necessary infrastructure for trade (Field Research, 2016). In addition to these challenges, growth in the MRO industry for export requires improved air traffic infrastructure; the Ninoy Aquino International Airport (NAIA) in Manila is operating at maximum capacity and delays and congestion are commonplace.

Energy Supply: As with infrastructure, the issue of the cost and supply of energy in the Philippines is an economy-wide constraint to industry development (IHS Connect, 2016). Energy availability plays different roles according to the stage of the value chain. This affects costs at both the components manufacturing and assembly stages. The components machining stage of the chain is a capital-intensive operation.³⁵ In the assembly stages of the chain, regulations require that operations be performed under specific and constant temperature conditions. In the tropical Philippines, this requires constant air-conditioning. With factory floors of several thousand square feet, energy quickly becomes the highest overhead costs and

³⁵ A firm operating 200 CNC machines, for example, draws approximately 4MW of energy (Field Research, 2016).

reliability is a key issue. All firms have thus invested in backup generators, again increasing the cost of operation (Field Research, 2016).

Table 19 highlights the key stakeholders responsible for shaping these competitiveness factors in the country.

Table 19. Key Industry Stakeholders

Institution	Role	Influence
Private Sector Actors		
Aerospace Industries Association of the Philippines (AIAP)	Formed in 2012 to provide a platform to promote the interests of the emerging aerospace sector. AIAP's membership includes the four large foreign firms operating in the country, as well as a large number of machining and tooling firms that are either already engaged in the industry or wish to enter the sector.	Organization was charged with drafting the industry roadmap representing the industry's policy requests. Important matchmaking organization with membership of the Tier 1s to help Tier 3 suppliers meet their requirements.
Philippines Aerospace Development Corporation, Department of Transportation and Communications	Established in 1973 as part of the government's attempt to develop a local aircraft industry, the organization today is mostly responsible for MRO activities for the national airline and the Philippines Airforce. It is an FAA Part 145 Certified Repair Station.	Organization's experience to date has largely been in MRO activities for the defense and general aviation sectors.
Public Sector Actors		
Civil Aviation Authority of the Philippines, Department of Transportation and Communications	Tasked with establishing, monitoring and enforcing air safety regulations for the civil aviation sector in the Philippines and developing aviation safety agreements with others countries.	Organization has been improving of late, but the group's inadequate track record in safety management led to the US and EU banning Philippine airlines in 2008 and 2010 respectively. These bans were subsequently lifted in 2014 & 2015.
Philippines Economic Zone Authority (PEZA)	PEZA serves a dual role, managing both the granting of EPZ incentives across the country, as well as directly engaging in the promotion of FDI in the country. The organization provides a one-stop-shop for all issues regarding investments and exports.	PEZA's leadership under Dr. Lilia De Lima has provided important continuity to the investment regime in the country. Tier 1s investing in the industry highlight the importance of PEZA support services in the country's competitiveness.
Department of Trade and Industry	Tasked with coordinating with the private sector to grow the manufacturing sector in the country; launched the roadmaps initiative in 2012.	Its attached agency, the Board of Investments, reviews and approves applications for investment incentives for the industry. Coordinating agency of technical working groups to overcome industry binding constraints.
Strategic Trade Management Office	New office tasked with designing and implementing new export controls for specific controlled products, including dual-use technologies used in the aerospace and defense sector.	The timely establishment and operation of this office will shape the potential for the country to join the Wassenaar Arrangement which would facilitate the attraction of aerospace manufacturers also in the defense sector.

Educational Institutions		
Commission for Higher Education (CHED)	CHED is responsible for overseeing higher education in the country. Responsibilities include formulation of policy and programming such as foreign scholarships and training and accreditation of tertiary educational institutions.	There are a number of scholarship and study abroad programs coordinated by CHED which are applicable to the industry.
PATTs College of Aeronautics and Philippines State College of Aeronautics – Institute of Engineering and Technology	Leading aeronautical colleges offering a 5-year Bachelor of Science in Aerospace Engineering and Aviation Electronics Technology.	The majority of graduates go into MRO operations and regulatory roles in the government rather than to the manufacturing sector.
University of the Philippines, De La Salle University	Leading engineering universities providing human capital for the manufacturing sector.	Both are considered to graduate the best students in the country.

Source: Authors.

4.5 Comparing Philippine Aerospace GVC Participation with Other Industry Players

As illustrated by discussions earlier in the paper, the Philippines must compete on a global and regional level with a number of players. On a global level, in order to carve out a niche, the Philippines must be competitive not only with the large traditional aerospace manufacturing hubs, but also with other emerging locations which have already established a foothold in the industry. To fully understand the country's position and potential, it is important to compare the country to both global and regional competitors. This section therefore draws comparisons between the Philippines and the two emerging players competing in the aerospace industry analyzed earlier, Mexico and Malaysia (see Section 1.9 for discussions of the aerospace sector in these countries). Specifically, comparisons are drawn on the size of the industry, certifications, as well as key elements of the institutional context in each country. Finally, key lessons from the experiences of these two countries are highlighted for the Philippines case.

The Philippines is the smallest participant of these three countries in the aerospace GVC, with just 20% and 30% of the exports of Mexico and Malaysia respectively. This is also reflected in the number of companies in each location, where the Philippines has just 10 firms. Mexico has been the most successful in attracting firms and developing local suppliers, with close to 300 firms in the business. These include leading firms in all tiers, such as Bombardier (airframes), GE Aviation (engines), Labial Power (electrical wire harnesses) and Meggitt (braking systems). Mexico's experience in the automotive and electronics industry helped to drive this development. In general, Mexico and Malaysia have concentrated on specific systems or operations. Mexico adopted a regional approach where each cluster focused on one aerospace system, while Malaysia focused on composites for airframes and MRO operations. The Philippines thus far has developed competencies in two areas, interiors and flight controls.

Industry employment in the Philippines remains a fraction of that in these other countries, although average firm size is considerably larger, illustrative of the lower-value more labor

intense operations being undertaken in the country to date. Growth of the sector in all three countries has been supported by a very strong workforce development component, but with just a slightly larger population (122 million versus 100 million), Mexico graduates twice the number of engineers as the Philippines. At the same time, the Philippines is rapidly ramping up its supply of aerospace engineers, and in 2015, universities were already graduating half the number of aerospace engineers in Malaysia.

Table 20. The Philippines, Malaysia and Mexico: Indicators in the Aerospace GVC, 2014

Country	Exports (US\$ billion)	No. of Firms	Jobs	Major Systems Operations	AS 9100 Certified Firms	FAA Certified Stations	Member of Wassenaar Arrangement	Key BASAs	Dedicated Industrial Parks
Philippines	0.6	10	6,000	Interiors Flight controls	9 (90%)	8	No – Legislation in progress	None	No
Malaysia	1.1	159	19,500	Airframes MRO services	41 (26%)	15	No – Legislation in progress	US, EU & China amongst others	Yes
Mexico	3.3	289	45-50,000	Interiors Engines Electrical Landing gear MRO services	169 (58%)	29	Yes (2011)	41 countries (US & EU)	Yes

Source: Authors based on FAA (2016b); International Aerospace Quality Group (2016).

Note: Exports only include manufactured parts, components and subassemblies, and final craft. Services exports, such MRO services are included.

As a recent entrant to the industry, the Philippines has a strong certification background with most firms operating in the sector already holding AS 9100 certifications. Uptake of certification in Mexico has been slightly slower, partly owing to the fact that many of these firms are legacy operations that have been in the industry since before the AS9100 system was integrated.

The Philippines has been slower than the other two countries to adopt policy changes to enhance the industry. Both Mexico and Malaysia have established national aerospace strategies, and instituted a number of bilateral air safety agreements, key for facilitating airworthiness certification in manufacturing and allowing air traffic flows required to boost MRO operations. Mexico has been a member of the Wassenaar Arrangement since 2011 helping to boost aerospace and defense manufacturing exports. The Philippines and Malaysia have both initiated legislation to improve export controls necessary for joining this arrangement.

Both Mexico and Malaysia have also developed dedicated industrial complexes, with international airports to support the flow of imports and exports of components and final craft in both manufacturing and services. The Philippines remains largely constrained to the

congested international airport in Manila, although the traffic is beginning to flow through the airport in Clark.

Based on the experience of these two competitors, four key lessons can be deduced for the Philippines. First, coordination in development of a national strategy was essential in both countries. Mexico prevented its states from competing against each other by using coordination mechanisms to develop complementary competencies across its clusters. Malaysia developed an inter-ministerial council – the Malaysia Aerospace Council to collaborate in overcoming binding constraints for the industry. Second, industry growth was targeted on specific segments of the industry. Malaysia focused specifically on developing manufacturing competencies in the composites sector. This targeted approach has helped to attract key investors and positioned Malaysia as an important player in composites. Today, the country hosts one of the primary manufacturing locations of Spirit Aerosystems, the leading Tier 1 provider of airframes outside of the US. Third, Mexico focused on attracting firms in all tiers of the supply chain, while simultaneously supporting local firms. This was important for growth in the industry, as local firms were not large or technologically sophisticated enough to meet the supply needs of all Tier 1s in the country. Tier 1s cannot operate efficiently without a strong Tier 2 supply base nearby. Finally, both countries have invested heavily in engineering programs – including aerospace, electronics, electrical and mechanical engineering. The availability of lower-cost, qualified engineers is an essential factor for industry expansion.

4.6 Potential Upgrading Trajectories for the Philippine Aerospace Sector

The Philippines has demonstrated its competitiveness as an emerging location in the manufacture of the product group currently produced in the country, yet as one of the most recent entrants to the aerospace GVC, the Philippines needs to consolidate its current position within the chain and build critical mass and credibility in the sector before pursuing aggressive upgrading. In the current context of strong competition, and drawing on the experience of Mexico and Malaysia amongst others, the following upgrading trajectories have been identified. Strong demand globally suggests that opportunities will expand in the chain as Tier 1 suppliers need to increase their production operations to meet the volume requirements of the aviation markets.

- I. **Process Upgrading to Deepen the Supply Chain (Short Term):** The experience in the country to date in developing the capabilities to meet the needs of the aerospace industry has been generally positive, yet considerable additional process upgrading is still required. Many additional processes including multi-axis machining, chemical and heat treatment are required to expand the number of product parts that can be manufactured locally. These suppliers must be AS9100 and NADCAP certified in order to facilitate their entry into the GVC. Generally speaking, the industry requires a larger certified supply base, in both existing capabilities to increase volume of current products and the new capabilities described above to expand the number of product parts. Process upgrading of existing suppliers will thus need to be complemented by the entry of new suppliers to meet the volume requirements of the Tier 1s. Moving into the aerospace sector supply chain can offer suppliers to the automotive and electronics sector with an

alternative market.

2. **Product Upgrading into More and Higher Value Products in Two Existing Aircraft Systems: Interiors and Flight Controls (Short Term).** The experience of the clusters in Mexico and Malaysia in the aerospace manufacturing industry highlights the importance of establishing credibility in a small number of systems before trying to expand broadly across the industry. Thus, first, the Philippines should focus on demonstrating its capabilities by broadening the number of products in the two aircraft systems in which it currently participates – Interiors and Flight Controls systems. Organic growth has indicated that the Philippines is already somewhat competitive in these segments, with existing capabilities. In the Interiors segment, for example, additional higher value products which could be produced include aircraft seats, oxygen systems and lighting. These systems are projected to have high future demand in both the prime market and the after-market segment for retrofitting planes. Demand for seats is expected to be over 6 million in the next ten years; an important share of which will be customized, leveraging the Philippines strengths for low volume, high mix, but low cost manufacturing (Broderick, 2016a). Growth in these systems areas would avoid direct competition for investment with other countries in the ASEAN Economic Community, such as Malaysia (airframes & MRO) and Singapore (engines & MRO) which already offer proven low-cost and experience in the aerospace sector.
3. **Product Upgrading: Leveraging Automotive Success for Entry into the Electrical Systems (Short to Medium Term):** In addition to the two sectors with existing aerospace capabilities, low-cost expertise in wire harnesses for the automotive sector could be leveraged to enter the electrical systems segment for aircraft. Chihuahua, Mexico offers one example of leveraging automotive success in wiring systems for the aircraft industry. The Philippines has developed strong capabilities in the production of wire harnesses for cars over the past two decades, and is currently the fourth largest global producer of these systems. The size of aeronautic electrical systems has expanded alongside the size of aircraft; a single A380, for example, has 500km of wires. This has increased the labor intensity of these products. To date, however, with the exception of Mexico, there has been little offshoring of the wire harness manufacturing with the major bases located in Europe and the US. While wire harness manufacturing in the aerospace sector requires considerable investments in achieving certification, as well as investing in new equipment, the Philippines has a strong base of technicians with capabilities in reading wire harness schematics and preparing them. This upgrading trajectory is discrete from upgrading in the interiors and flight controls systems; however, these are adjacent systems with evident synergies such as wiring for cabin lighting and in-flight entertainment. It likely will depend on some process upgrading to ensure necessary supply chain capabilities are present in the country.
4. **Upgrading of MRO Operations (Short to Medium Term):** The Philippines has begun to make headway in the growing MRO industry in the Asia-Pacific Region. Strong

growth of the Asia-Pacific fleet over the past two decades is forecast to continue, reaching 21% of the global market in 2016 (Aviation Week & Space Technology, 2016; Technavio, 2015). Rising costs in leading location, Singapore, have made it more difficult for the country to compete, creating opportunities for the Philippines and others in the region to enter the sector as alternative, lower-cost destinations. Indonesia, Malaysia and Thailand are all seeking to expand their presence in the MRO segment (Torr, 2014). For the Philippines to leverage this upgrading trajectory and continue to develop as a competitive alternative to its peers in the region, it must overcome binding constraints in infrastructure, with the NAIA airport already at capacity (IATA, 2015), and would be dependent on developing capabilities in Clark. This upgrading trajectory can be considered discrete from the others included here. MRO operations are unlikely to become significant drivers of manufacturing of MRO parts in the country in the short to medium term.

5. **Market Upgrading to Serve Global Suppliers based in other countries (Medium to Long Term):** With growing local capabilities, local suppliers may be able to leverage the opportunity to serve other global suppliers in the industry that are not located in the Philippines. With the industry growing in the region, a large number of Tier 1 suppliers have established operations in Singapore and Malaysia amongst others. One firm has already begun to work collaboratively with a peer in Malaysia (Field Research, 2016). Developing complementary supply chain capabilities can help to gain access to these markets, and take advantage of the opportunities of increased trade afforded through AEC.
6. **Market Upgrading into the After-market Product Segment (Medium to Long Term):** As the country gains capabilities in the manufacturing sector and resolves challenges with respect to logistics, there will be potential to upgrade into the after-market product segment to service and supply spare parts, as Moog has already done. This is a very lucrative segment of the market, with values of two to three times the original product value and is served by both original equipment manufacturers and smaller third party firms. This product segment is driven by even higher mix, lower volumes than the original assembly operations and requires rapid turnaround time and very efficient logistics operations. This trajectory depends on successful upgrading of processes and capabilities in the country in order to be able to meet the demands of the sector.

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6. Appendix

Table 20. Aerospace Product Categories

VC Stage	VC Sectors	HS Codes (HS02)	HS Code Six-Digit Descriptions	VC Subsectors
Final Products	Helicopters	880211 880212	880211: Helicopters of an unladen weight ≤ 2000kg 880212: Helicopters of an unladen weight > 2000kg	
	Airplanes	880220 880230 880240	Airplanes and other aircraft, of an unladen weight: 880220: not exceeding 2,000 kg 880230: >2000 kg but not >15000kg 880240: >15000kg	
Sub-assemblies	Landing Gear	880320	880320: Under-carriages & parts thereof of goods of 88.01/88.02	Under-carriages
	Aircraft parts & assemblies (Generic)	880330	880330: Parts of airplanes/helicopters, other than propellers, rotors, under-carriages & parts thereof	
	Propellers & Rotors	880310*	880310: Propellers & rotors & parts thereof, of goods of 88.01/88.02	
	Other Parts	880390*	880390: Parts of goods of 88.01/88.02, nes in 88.03	
	Main Engine (Propulsion)	841111 841112 841121 841122 841181 841182	841111: Turbo-jets of a thrust ≤ 25 kN 841112: Turbo-jets of a thrust > 25 kN 841121: Turbo-propellers of a power ≤ 1,100 kW 841122: Turbo-propellers of a power > 1,100 kW 841181: Other gas turbines of a power ≤ 5,000 kW 841182: Other gas turbines of a power > 5,000 kW	
	Other Engines (Other on-board engines)	840710 841210**	840710: Spark-ignition reciprocating/rotary internal combustion piston engines for aircraft 841210: Reaction engines other than turbo-jets	
	Launching Gear	880510*	880510: Aircraft launching gear & parts thereof; deck-arrestor/similar gear & parts thereof	
	Ground Trainers	880529*	880529: Ground flying trainers and parts: Ground flying trainers other than air combat simulators, & parts thereof	
	Interior	940110**	940110: Seats of a kind used for aircraft	Seats
Components	Main Engine	841191 841199	841191: Parts of the turbo-jets/turbo-propellers of 8411.11-8411.22 841199: Parts of the other gas turbines of 8411.81 & 8411.82	Parts
	Other Engines	840910	840910: Parts suit. for use solely/principally with the aircraft engines of 84.07	Parts
	Landing Gear	401130** 401213**	401130: New pneumatic tyres, rubber, used on aircraft 401213: Retreaded pneumatic tyres rubber, used on aircraft	Tires
	Electronic Instruments	901420 ³	901420: Instruments & appliances for aeronautical/space navigation (excl. compasses)	Navigation Systems

Source Authors based on Bamber and Gereffi (2013a).

Notes (*): indicates code was included in “Other 88” category in Bamber & Gereffi (2013). (**): Indicates code was not included; (1): also included in electrical and automotive definitions; (2) also included in automotive definition; (3) also included in electronics definition.

Table 21. Leading Export Destinations for Select Emerging Players in the Aerospace GVC

	Value (US\$ millions)				Share of Country Aerospace Exports (%)			
	2007	2010	2012	2014	2007	2010	2012	2014
Reporters								
Singapore	5,225	7,220	9,932	11,449				
US	1,045	1,247	1,714	2,109	20%	17%	17%	18%
China	602	487	704	1,236	12%	7%	7%	11%
UK	451	741	1,114	1,113	9%	10%	11%	10%
Japan	427	403	692	821	8%	6%	7%	7%
France	118	286	366	643	2%	4%	4%	6%
India	503	1,900	2,055	7,456				
Sri Lanka	0	1	1	1,943	0%	0%	0%	26%
UAE	8	60	80	1,232	2%	3%	4%	17%
US	56	590	322	582	11%	31%	16%	8%
UK	38	192	308	484	8%	10%	15%	6%
Singapore	59	248	158	413	12%	13%	8%	6%
Mexico	2,081	2,170	2,684	3,269				
US	1,676	1,668	2,214	2,840	81%	77%	82%	87%
France	60	70	110	81	3%	3%	4%	2%
UK	57	85	60	74	3%	4%	2%	2%
Canada	47	56	38	50	2%	3%	1%	2%
Japan	40	38	20	47	2%	2%	1%	1%
Poland	588	1,441	1,962	2,778				
US	138	534	785	915	23%	37%	40%	33%
Canada	221	361	437	460	38%	25%	22%	17%
Germany	27	103	116	183	5%	7%	6%	7%
Japan	3	33	15	137	1%	2%	1%	5%
Moldova	0	0	0	126	0%	0%	0%	5%
Thailand	1,911	1,669	1,629	1,677				
Singapore	718	556	444	501	38%	33%	27%	30%
US	364	231	231	236	19%	14%	14%	14%
China	20	131	147	131	1%	8%	9%	8%
UK	58	32	91	124	3%	2%	6%	7%
Germany	41	66	119	122	2%	4%	7%	7%
Malaysia	1,158	956	879	1,057				
Singapore	470	340	202	253	41%	36%	23%	24%
US	189	223	229	180	16%	23%	26%	17%
UK	143	135	162	168	12%	14%	18%	16%
Japan	62	27	10	68	5%	3%	1%	6%
Thailand	29	14	10	63	2%	1%	1%	6%

Source: UNComtrade, HS02 6D codes, Reporters exports to the World, Retrieved 10/29/15.

Note: US and UK data added for all HS88. This includes HS8801 and 8804 which are otherwise not included for other countries. Need because U.S. only reports under HS880000 for 2009 onwards and UK did not report at the 6D level in 2007, 2010 or 2012.