

Global MRO Market Economic Assessment

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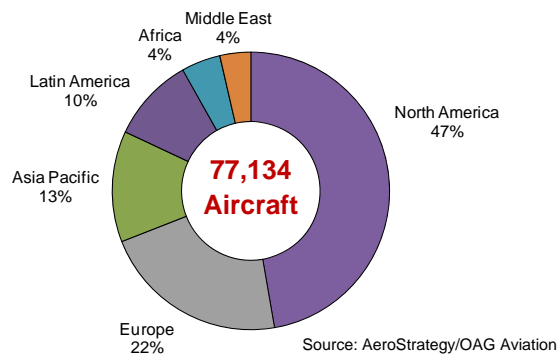
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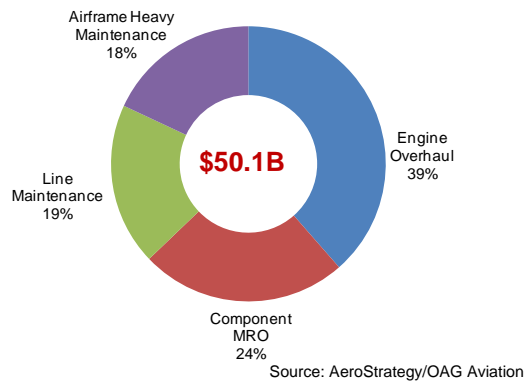
1. EXECUTIVE SUMMARY

2008 WORLD CIVIL AVIATION FLEET



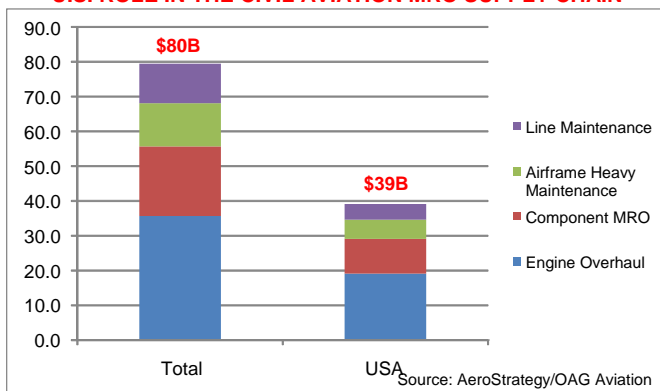
The world jet-powered civil aviation fleet consists of over 77,000 aircraft flying approximately 77 million hours per year. Nearly half of the fleet is located in North America (US and Canada), with approximately 37,000 aircraft. Europe is the next largest market with 16,800 aircraft, followed by Asia Pacific with nearly 10,000 aircraft.

2008 WORLD CIVIL MRO MARKET



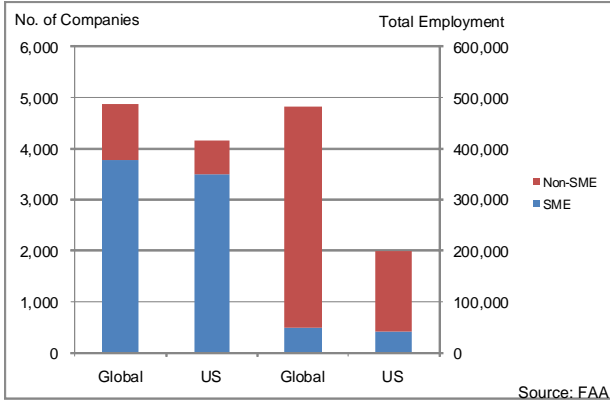
The civil aviation maintenance, preventive maintenance and alteration (MRO) market is divided into four distinct market segments: airframe heavy maintenance, engine overhaul, component MRO and line maintenance. Spending in the MRO market is in excess of \$50B; North America represents the largest geographic market – estimated at \$19.4B.

U.S. ROLE IN THE CIVIL AVIATION MRO SUPPLY CHAIN



Factoring spending by overhaul shops on service parts and specialty processes, the civil MRO market generates \$80B in economic activity. The United States plays a prominent role in this activity; U.S. suppliers account for an estimated \$39B – nearly 50 percent of the total. Indeed, North America is a major net exporter of aviation maintenance services; enjoying a \$2.4 billion positive balance of trade in this area. While North America is a slight net importer of heavy airframe maintenance services, it has \$1.4B and \$1.2B trade surpluses in the engine overhaul and component maintenance services markets, respectively. North America's competitive advantage is significant; one dollar of spending on airframe heavy maintenance generates just \$1.38 in additional economic activity, while a dollar spent on engine overhaul and component maintenance services generates \$1.85 and \$1.67, respectively.

CIVIL AVIATION MRO EMPLOYMENT

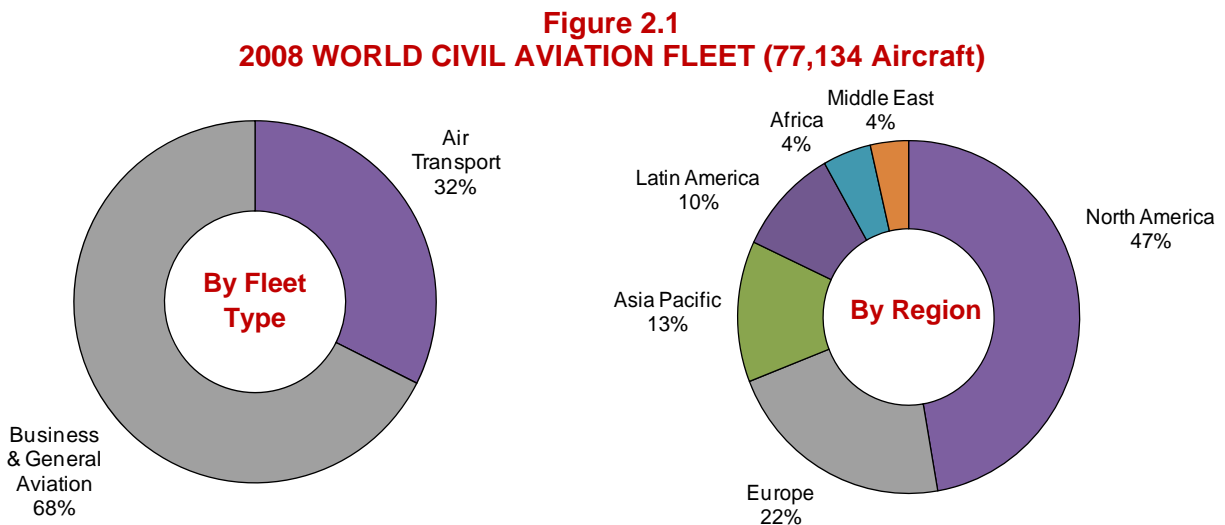


Approximately 480,000 employees in more than 4,800 firms worldwide participate in the civil MRO supply chain (*all employment data from FAA Database*). Nearly 80 percent of firms are small or medium-sized enterprises (SMEs). Globally, there are over 290,000 technicians – 24 percent of which are FAA-certificated. In the United States there are nearly 4,200 firms with more than 200,000 employees in the civil MRO market. SMEs comprise 85 percent of all firms and account for 21 percent of all employment. There are over 145,000 technicians in the United States and approximately half are FAA-certificated.

2. INTRODUCTION

The world jet-powered civil aviation fleet consists of over 77,000 aircraft (*Figure 2.1*). There are over 52,000 business and general (BGA) aircraft representing over two-thirds of the world civil fleet. There are over 25,000 aircraft in the air transport fleet. Nearly half of the fleet is located in North America representing nearly 37,000 aircraft. Europe is the next largest market with 16,800 aircraft followed by Asia Pacific with nearly 10,000 aircraft.

The civil aviation fleet flies approximately 77 million hours per year. Air transport aircraft, although only 32 percent of the fleet, fly 60 million hours per year or nearly 80 percent of the civil aviation total. On average, air transport aircraft fly 2,400 hours per year versus 330 hours per year for BGA aircraft. Aircraft flight hours or utilization is a key driver for MRO services.



Source: AeroStrategy/OAG Aviation

The civil MRO market is segmented into four distinct markets: airframe heavy maintenance, engine overhaul, component MRO, and line maintenance.

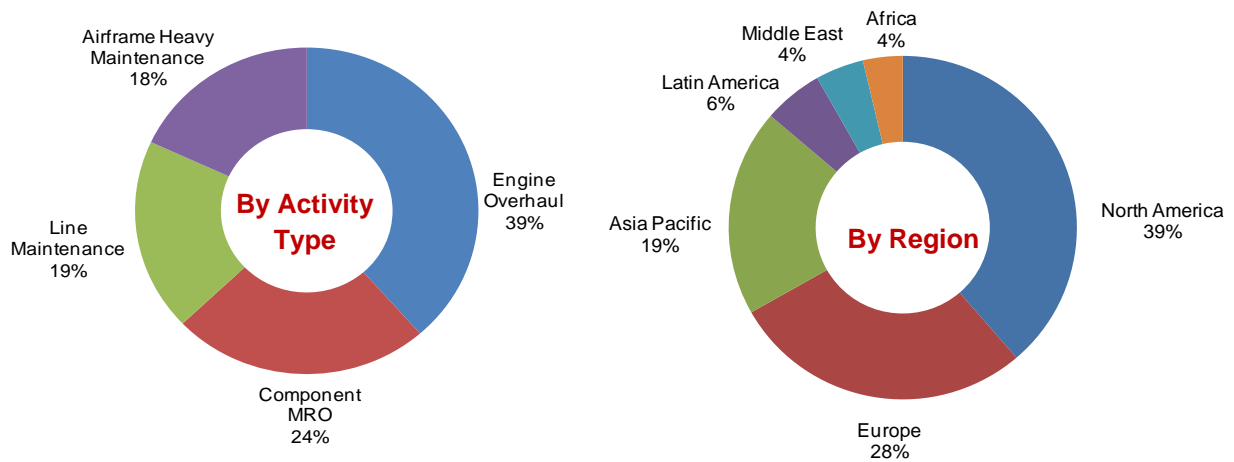
- **Airframe Heavy Maintenance** - A detailed inspection of the airframe and components – including any applicable corrosion prevention programs and comprehensive structural inspection and overhaul of the aircraft.
- **Engine Overhaul** - Off-wing repair and replacement of parts to restore the engine to designed operational condition, to guidelines established by the engine manufacturer. Typically, the engine is disassembled, inspected, parts are repaired or replaced as necessary, re-assembled and tested.
- **Component MRO** - Maintenance, including repair and overhaul of aircraft components, which provide the basic functionality for aircraft flight including aircraft

control and navigation, communications, control surface movement, cabin air conditioning, electrical power, and braking.

- **Line Maintenance** - Light, regular maintenance checks that are carried out to ensure that the aircraft is fit for flight - including trouble shooting, defect rectification, overnight maintenance and component replacement.

The world civil aviation MRO market is estimated at over \$50B (Figure 2.2). Engine overhaul is the largest segment at \$19.3B followed by component MRO at \$12.2B. Line maintenance and airframe heavy maintenance are over \$9B each. North America is the largest geographic market – estimated at \$19.4B. Europe and Asia Pacific are the next largest markets at \$14.1B and \$9.8B, respectively.

Figure 2.2
2008 WORLD CIVIL MRO MARKET (\$50.1B)



Source: AeroStrategy/OAG Aviation

3. AIRFRAME HEAVY MAINTENANCE

3.1. Introduction

Airframe heavy maintenance is the inspection and repair of the aircraft airframe, performed at specified time intervals. These intervals are based upon the guidelines of the aircraft manufacturer, national aviation authority (Federal Aviation Administration (FAA), European Aviation Safety Agency (EASA), etc.) as further refined by the airline/operator. Ultimately, it is the individual airline’s choice, in compliance with national regulations, to establish heavy maintenance schedules that meet safety and operational requirements.

Scheduled inspections are typically based on a fixed number of flight hours. There are four levels of inspection for commercial jet aircraft, usually termed “A”, “B”, “C”, and “D” checks. A and B checks are normally considered part of line maintenance, which is discussed in Section 6. C and D checks are classified as “heavy maintenance” and are detailed below. The concepts for BGA market are much simpler.

Table 3.1
AIRFRAME HEAVY MAINTENANCE OVERVIEW

Market	Activity	Description	Frequency*	Turn-around Time*	Man-hrs required*
Air Transport	C Check	A detailed inspection of the airframe, components and accessories; some access panels are removed. Typically includes a portion of any applicable corrosion prevention programs	2,500 to 3,000 flight hrs	72 hrs (airlines with small fleets may require 7+ days)	2,000 to 4,000 hrs
	D Check	A comprehensive structural inspection and overhaul of the aircraft, intending to return it to its original condition (to the extent possible); interiors and most components are removed	20,000 to 24,000 flight hrs (approx. 5 to 8 yrs)	30 days	10,000 (smaller jets) to 50,000+ man-hrs (B747)
BGA	Minor	Inspections include check of fluid levels, tire pressure, lighting, etc.	300 to 500 flight hrs	Less than one day	4 to 15 hrs
	Major	A comprehensive structural inspection and overhaul of the aircraft (similar to a D-check)	3,000 – 6,000 flight hrs	5 to 7 days	2,000 to 5,000 hrs

*All values/intervals are approximate

Source: AeroStrategy

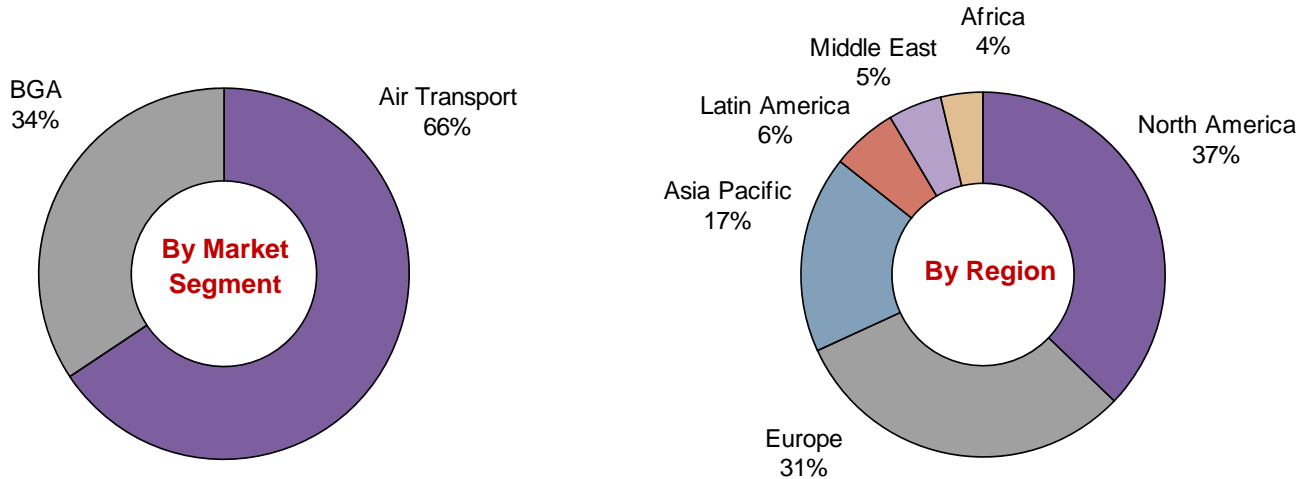
Nowadays there is a variety of blended approaches to heavy maintenance. To minimize aircraft downtime and improve labor efficiency, airlines typically undertake these checks in a series of progressive inspections, and D-check tasks are often divided and included into more frequent C-level inspections. Thus, an aircraft might receive a C1, C2, C3 and C4 check in sequence over many years, eliminating the need for a full D-check.

3.2. Market Description

The civil airframe heavy maintenance market is estimated at \$9.1B (Figure 3.2). Air transport is the largest market segment at \$6.0B or 66 percent of the total with BGA

representing \$3.1B or 34 percent. North America is the largest market, generating \$3.4B of total demand, followed closely by Europe at \$2.8B, with Asia Pacific coming in third at an estimated \$1.6B. Together, these markets represent over 85 percent of the global civil airframe heavy maintenance market.

Figure 3.2
2008 WORLD AIRFRAME MAINTENANCE OVERHAUL MARKET (\$9.1 BILLION)



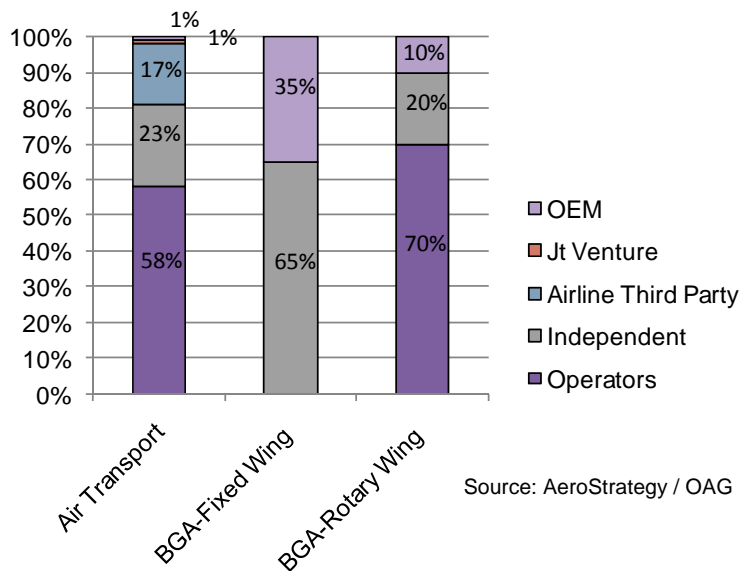
Source: AeroStrategy/OAG Aviation

There are four types of firms who perform airframe heavy maintenance (*Figure 3.3*):

- **Original Equipment Manufacturer (OEM)** – The involvement of air transport OEMs in airframe heavy maintenance is relatively limited. This is due in part to the labor-intensive nature of this maintenance activity. The largest OEMs - Airbus and Boeing - have a minimal role in the heavy maintenance market. In contrast, the two major regional jet manufacturers, Embraer and Bombardier, operate several heavy maintenance facilities in the United States. BGA OEMs (e.g., Cessna, Hawker Beech, Gulfstream, Dassault, Embraer, and Bombardier) are also actively involved in the market as many of their customers do not have the scale to establish the capability and look to the OEM for support. The main rotary wing OEMs are Bell, Eurocopter, and Sikorsky.
- **Operator** – Despite a recent trend towards contract maintenance, operators with in-house airframe maintenance capability perform the majority of their own heavy checks. Some of the largest entities in this category include British Airways, American Airlines, and Japan Airlines.
- **Independent** – Independent suppliers -- maintenance firms unrelated to either OEMs or airlines – are significant players in the heavy maintenance market. Independents typically enjoy the lowest labor costs of any supplier group. The largest companies in this supply category include ST Aerospace, SR Technics, ATS, AAR, and Timco.

- **Airline Third Party.** These companies are typically maintenance subsidiaries of airlines and undertake airframe MRO work for other airlines (as well as their parent). The largest companies in this category are Lufthansa Technik, Air France Industries/KLM Engineering, Ameco Beijing, and Singapore Airlines Engineering Company.

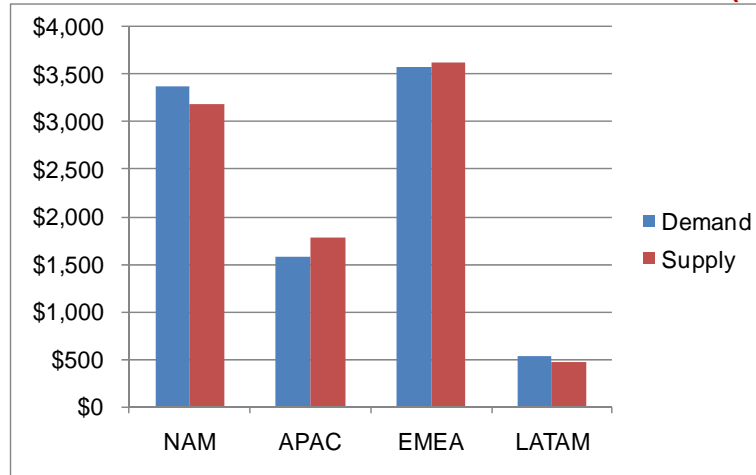
Figure 3.3
2008 AIRFRAME HEAVY MAINTENANCE PARTICIPANTS



The air transport heavy maintenance market structure is fundamentally different from BGA fixed wing. Air transport operators provide almost 60 percent of their total maintenance (\$4.5B), the balance is effectively split between independents and airline third parties. In BGA fixed wing, however, independent providers such as Jet Aviation accomplish almost two-thirds of the work for a total some \$1.1B; the balance is performed by OEMs. The structure of the BGA rotary wing is similar to air transport, where the operators perform the large majority of the work (70 percent or \$1B).

North American operators generate \$3.4B (Figure 3.4) of airframe heavy maintenance demand – over 85 percent of the airframe heavy maintenance is performed by suppliers domiciled in North America (Figure 3.5); Approximately \$435M of airframe heavy maintenance is sent to regions outside North America and an additional \$250M of airframe heavy maintenance is conducted for other regions – resulting in a total of \$3.2B of airframe heavy maintenance performed by North American airframe heavy maintenance suppliers. Europe, the Middle East, and Africa (EMEA) are net exporters of airframe heavy maintenance; EMEA operators generate \$3.6B of airframe heavy maintenance demand – nearly 95 percent of which is domiciled in EMEA with an additional \$239M supplied to other regions.

Figure 3.4
AIRFRAME HEAVY MAINTENANCE SUPPLY & DEMAND (\$M)



Source: AeroStrategy/OAG Aviation

Figure 3.5
AIRFRAME HEAVY MAINTENANCE INTRA-REGION FLOW

Market Segment	Demand By Operator Region		Provider Region			
			NAM	APAC	EMEA	LATAM
Air Transport	NAM	\$1,807M	82%	13%	3%	2%
	APAC	\$1,269M	0%	96%	4%	0%
	EMEA	\$2,642M	1%	2%	97%	0%
	LATAM	\$234M	5%	0%	11%	84%
Business & General Aviation	NAM	\$1,565M	93%	1%	4%	2%
	APAC	\$316M	14%	80%	5%	1%
	EMEA	\$934M	10%	1%	88%	1%
	LATAM	\$298M	25%	0%	10%	65%

Source: AeroStrategy

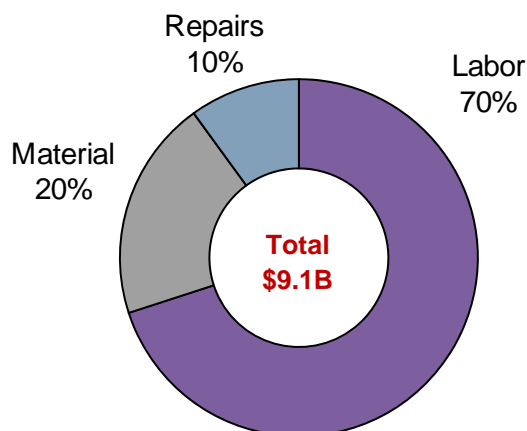
3.3. Cost Structure

There are three primary cost elements in airframe heavy maintenance (*Figure 3.6*): material, labor and repair/specialty services.

- Labor** – Labor is the dominant component of heavy maintenance cost, accounting for 70 percent. This includes direct labor required to, for example, remove interiors and exterior access panels, inspection, repair (if necessary), and reassembly. It also includes general and administrative overhead charges and employee benefits. Globally, according to the FAA, there are 221,578 technicians engaged in airframe heavy maintenance, nearly 30 percent of whom are FAA-certificated as mechanics or repairmen. In the United States there are 101,946 technicians – approximately 54 percent or 55,132 are FAA-certificated as mechanics or repairmen. The percentage of certificated persons varies by the type of overhaul facility. For an independent airframe heavy maintenance facility, between 50 and 70 percent of the technicians are FAA-certificated. This compares to an airline MRO where over 90 percent of technicians are FAA-certificated. This provides the airlines with the flexibility to perform some line maintenance activities (e.g., A checks) with the same resources.

- **Material** – This is the second largest cost category at 20 percent of the total. This includes “consumables” such as solvents, hardware (e.g., fasteners and standard parts), as well as airframe parts. Note that the airline customer will typically provide any required replacement “rotatable” components.
- **Repair/Specialty Services** – Outside repairs and services, such as non-destructive inspection, composite repairs, seat repairs, and fuel tank inspection, accounts for 10 percent or less of the cost. These repairs may be contracted to independent or specialized shops.

Figure 3.6
AIRFRAME HEAVY MAINTENANCE COST STRUCTURE



Source: AeroStrategy

3.4. Supply Chain

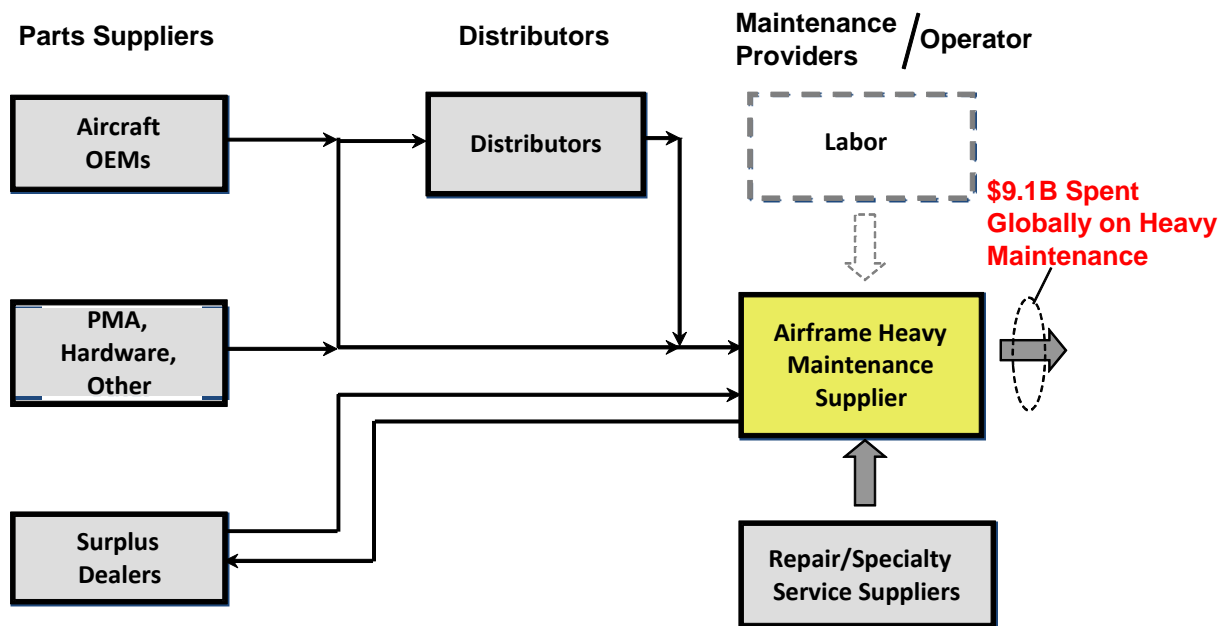
There are three main supply sources for aircraft heavy maintenance (*Figure 3.7*): part suppliers, distributors, and repair/specialty service suppliers. On occasion, heavy maintenance suppliers will turn to contract labor agencies to assist with staffing peaks. Unlike engine MRO work, however, the material required is quite small.

- **Part Suppliers** – There are three primary sources for parts: OEMs, Part Manufacturer Approval (PMA) holders and hardware manufacturers, and surplus dealers. Air transport and BGA OEMs, the source of most airframe service parts, were discussed previously. The PMA market is rather small and focused primarily on interiors. Companies such as Heico, Wencor and Regent are active in this space. Hardware including “fasteners” is routinely replaced during MRO activities; two of the largest companies are SPS and Alcoa Fastening Systems. The last source, surplus dealers, is small in terms of material flow. The exception is providing material for older aircraft, such as the 737-200. Companies that specialize in surplus include AAR, Volvo Aero, Kellstrom, and AirLiance. Approximately two-thirds of surplus dealers are domiciled in the United States. On average, airframe heavy MRO providers work with 10-15 material suppliers including OEMs, PMAs and surplus

dealers; for consumables and hardware, the number of parts suppliers can be in the dozens.

- **Distributors** – Distributors are a common intermediary between parts suppliers and heavy maintenance facilities. Key distributors are Aviall, Satair, Wesco, Interturbine, B/E Aerospace and Avio Diepen, with Aviall (now owned by Boeing) easily the largest of this group. Over 60 percent of distributors are domiciled in the United States. On average, airframe heavy MRO providers work primarily with three to four major distributors and a dozen or so smaller ones for hardware and consumables.
- **Repair/Specialty Services** – Specialty repairs include repairs to interiors (such as seats and galleys) as well as structural repairs to airframe parts, including both metallic and composites, e.g., composite fairings and radomes. Structural repairs are often completed by local SME machine shops. On average, airframe heavy MRO providers work with five to ten repair/specialty service suppliers.

Figure 3.7
AIRFRAME HEAVY MAINTENANCE SUPPLY CHAIN



Source: AeroStrategy

3.5. Economic Activity

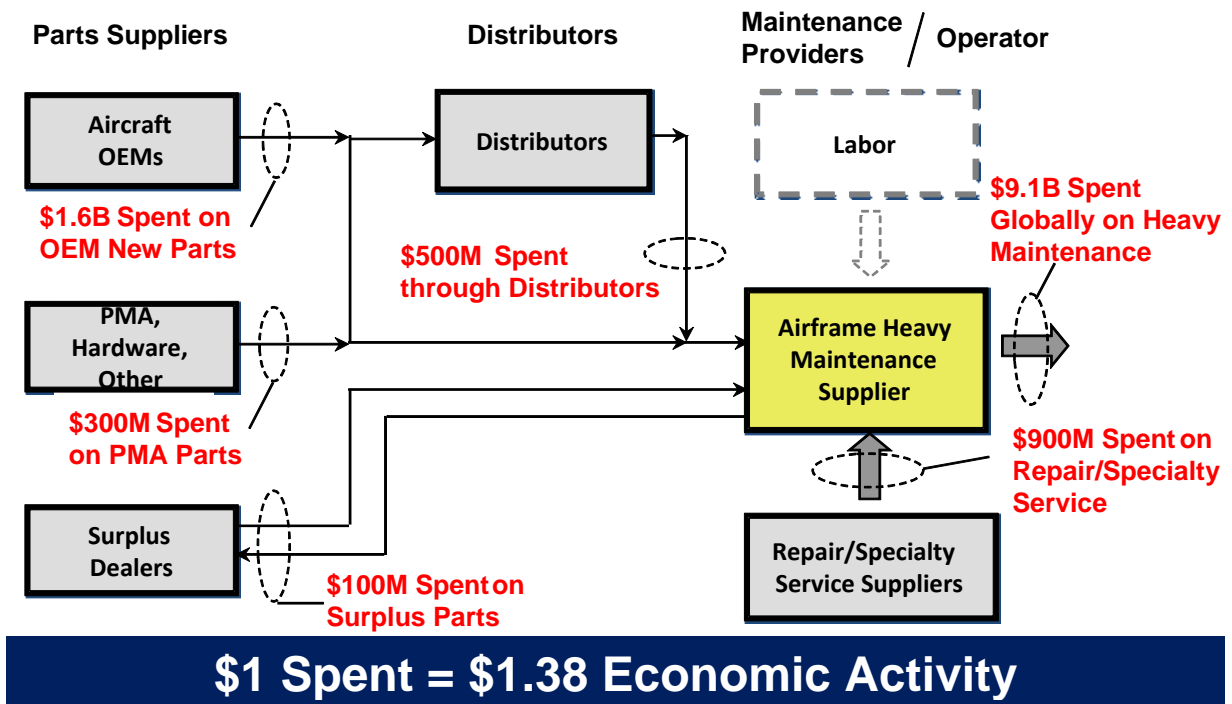
Globally, operators spend \$9.1B on airframe heavy maintenance which generates \$12.5B in overall economic activity in the supply chain (Figure 3.8). For every dollar spent on airframe heavy maintenance, an additional \$1.38 in economic activity is generated. Of the \$12.5B of global economic activity, the United States generates \$5.4B (Figure 3.9).

Labor internal to the airframe heavy maintenance facility, employs 359,134 workers with 2,691 suppliers (Figure 3.10); nearly 80 percent of the suppliers are SMEs, employing

over 26,000 people worldwide. In the United States there are 136,476 workers in the airframe heavy maintenance supply chain with 2,355 suppliers; nearly 85 percent of the suppliers in the United States are SMEs – employing nearly 24,000 people.

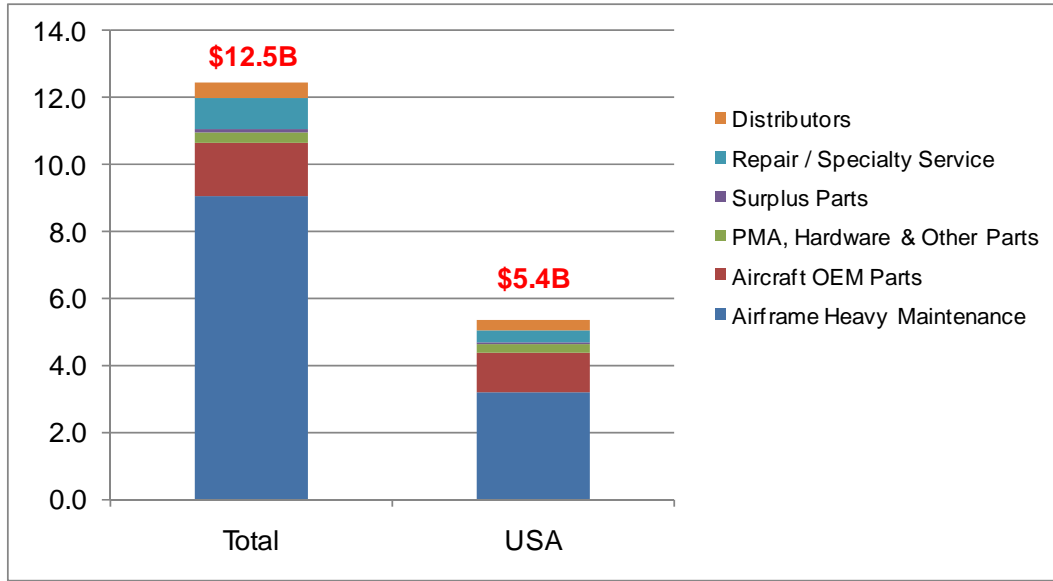
Airframe heavy maintenance material consumption is the largest economic activity outside of the MRO service; approximately \$2.0B per year is spent on material globally and over 75 percent of this figure is with suppliers domiciled in the United States, or approximately \$1.5B annually. Repair/specialty service and distribution generate \$900M and \$500M respectively; approximately half of the suppliers are domiciled in the United States.

Figure 3.8
ECONOMIC ACTIVITY GENERATED BY AIRFRAME HEAVY MAINTENANCE



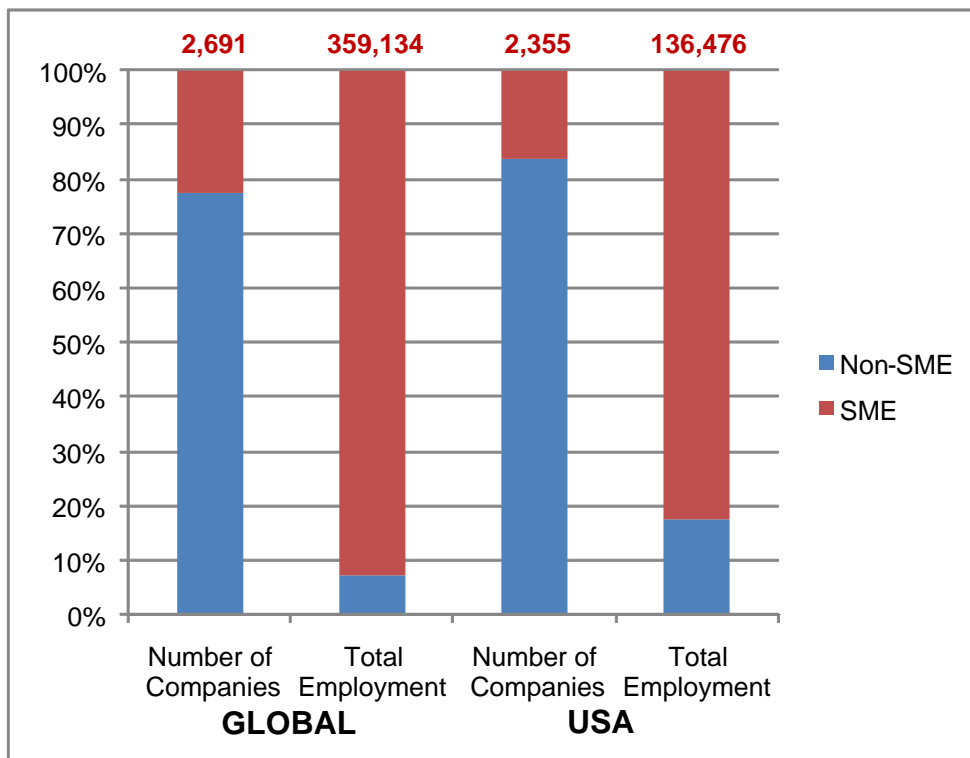
Source: Interviews, AeroStrategy

Figure 3.9
ROLE OF U.S. IN THE AIRFRAME HEAVY MAINTENANCE SUPPLY CHAIN



Source: AeroStrategy

Figure 3.10
AIRFRAME HEAVY MAINTENANCE EMPLOYMENT



Source: FAA

4. ENGINE OVERHAUL

4.1. Introduction

Engine overhaul is defined as off-wing repair and replacement of parts to restore the engine to designed operational condition in accordance with guidelines established by the engine manufacturer (*Figure 4.1*). Typically, the engine is disassembled, inspected and parts are repaired or replaced as necessary. The engine is then re-assembled and tested before being reinstalled on the aircraft. For air transport engines, engine overhaul is performed on an as-needed basis, except for the replacement of life-limited parts (LLP) which occurs at fixed times established by the civil aviation authority.

For business and general aviation (BGA), engine overhaul is performed at specified time intervals according to guidelines established by the engine manufacturer; additionally, some BGA engines also have scheduled hot-section inspections (HSI) which involves borescope examinations to detect wear inside the engine.

Figure 4.1
ENGINE OVERHAUL DEFINITION

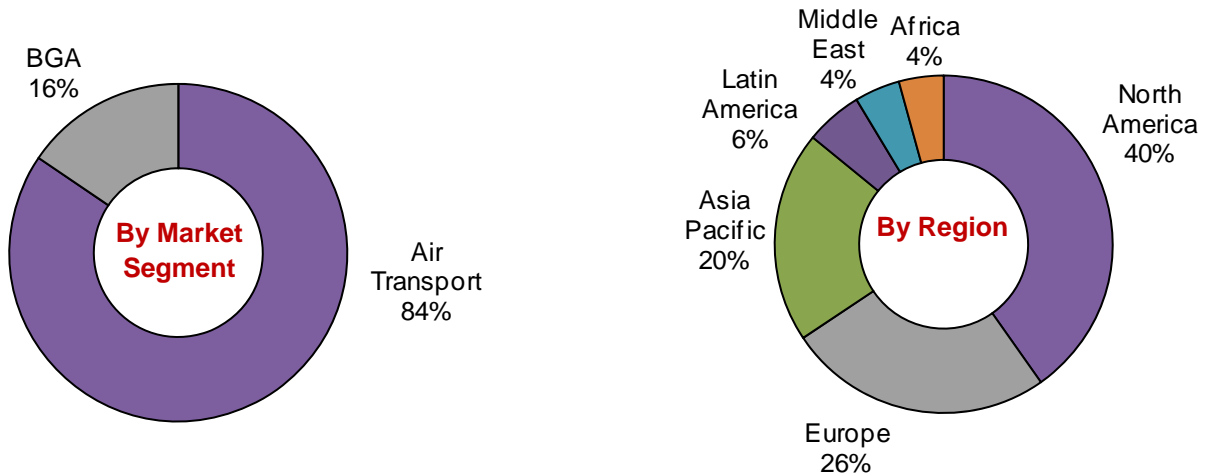
Market	Activity	Description	Frequency	Typical Cost
Air Transport	Overhaul	Disassemble, inspect, repair or replacement parts, reassemble and test	4,500 hrs to 24,000 hrs	\$450,000 to \$5,500,000
BGA	Hot Section Inspection	Borecope inspection of hot-section	1,000 hrs to 3,000 hrs	\$25,000 to \$150,000
	Overhaul	Disassemble, inspect, repair or replacement parts, reassemble and test	3,500 hrs to 7,000 hrs	\$200,000 To \$800,000

Source: AeroStrategy

4.2. Market Description

The civil aircraft engine overhaul business is estimated to be \$19.3B (*Figure 4.2*). Air transport is the largest market segment at \$16.3B or 84 percent of the total market; BGA is the remaining 16 percent at \$3B. Regionally, North America is the largest market – generating \$7.8B of engine overhaul demand followed by Europe and Asia Pacific, which generate \$5B and \$4B in demand, respectively.

Figure 4.2
2008 WORLD ENGINE OVERHAUL MARKET (\$19.3 BILLION)

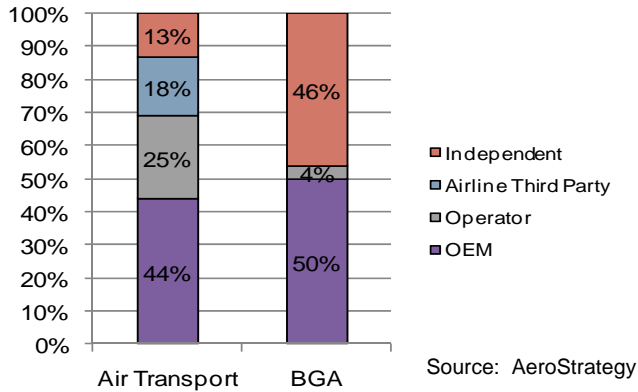


Source: AeroStrategy/OAG Aviation

There are four types of firms that perform engine overhaul work (*Figure 4.3*):

- **OEM** – OEMs are the largest providers of engine MRO services. The OEMs for air transport class engines include GE, Pratt & Whitney, Rolls-Royce, SNECMA, CFM International, and International Aero Engines. OEMs that service the BGA market include Pratt & Whitney Canada, Honeywell, Williams International, GE and Turbomeca.
- **Operator** – Operators with in-house engine overhaul capability include several major airlines: United, American, Japan Airlines and Iberia. Very few operators in the BGA market have the scale to overhaul their own engines.
- **Independent** – Independent engine MRO providers include firms unrelated to either OEMs or airlines; examples include Standard Aero, MTU, SR Technics, Aerothrust, Dallas Airmotive, Vector Aerospace, Aveos, Timco, Pacific Gas Turbine, and ST Aerospace.
- **Airline Third Party**. These providers are partially or fully owned by airlines and conduct overhauls for their parent company as well as third-party customers. Examples include as Delta Tech-Ops, Air France Industries and Lufthansa Technik.

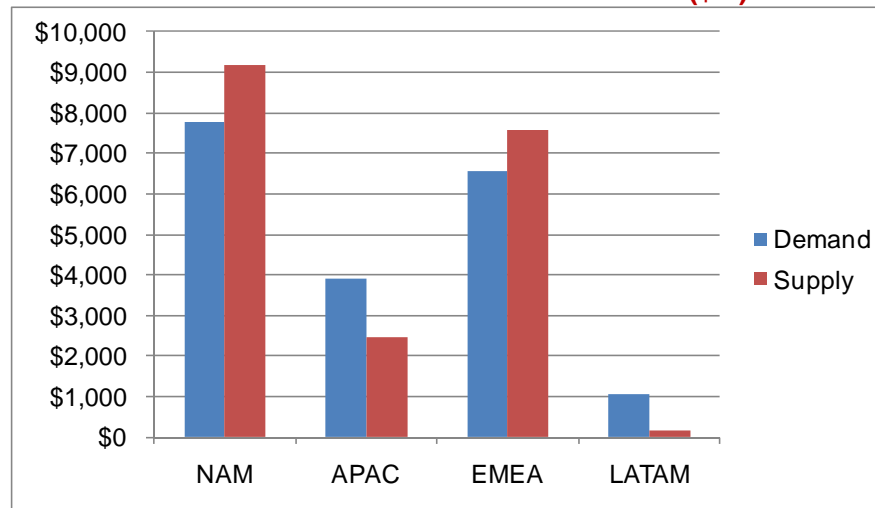
Figure 4.3
2008 ENGINE OVERHAUL PARTICIPANTS



Operators perform approximately 22 percent or \$4.2B of engine overhaul in-house; the remaining \$15.1B or 78 percent is performed by contractors, the largest of which are engine OEMs who perform 45 percent or \$8.7B of the work. The remaining \$3.5B and \$2.9B are performed by independents and airline third parties, respectively.

North American operators generate \$7.8B (Figure 4.4) of engine overhaul demand – over 80 percent of this work is performed by suppliers domiciled in North America (Figure 4.5). Approximately \$1.6B is sent to regions outside North America and an additional \$3B is performed for airlines from other regions – resulting in a total of \$9.2B of engine overhaul work performed by North American engine overhaul providers. EMEA operators generate \$6.6B of engine overhaul demand – nearly 30 percent of the work or \$1.5B flows to North American suppliers. Overall, North America has a \$1.4B positive balance of trade in this area.

Figure 4.4
ENGINE OVERHAUL SUPPLY & DEMAND (\$M)



Source: AeroStrategy/OAG Aviation

Figure 4.5
ENGINE OVERHAUL INTRA-REGION FLOW

Market Segment	Demand By Operator Region		Provider Region			
			NAM	APAC	EMEA	LATAM
Air Transport	NAM	\$6,088M	78%	2%	20%	0%
	APAC	\$3,644M	15%	53%	32%	0%
	EMEA	\$5,764M	25%	6%	70%	0%
	LATAM	\$826M	54%	2%	34%	10%
BGA	NAM	\$1,684M	82%	1%	15%	2%
	APAC	\$273M	60%	14%	25%	1%
	EMEA	\$807M	37%	1%	60%	2%
	LATAM	\$231M	60%	1%	25%	14%

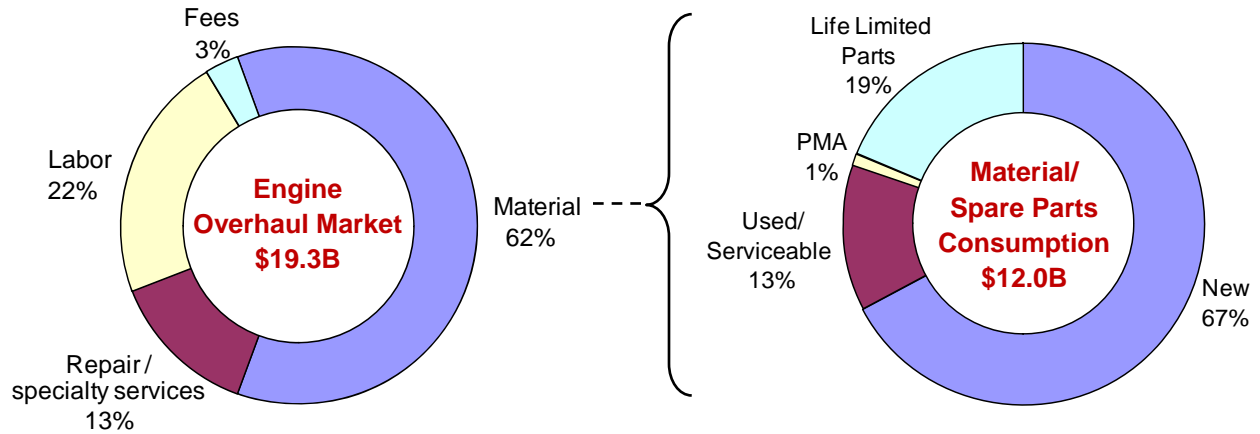
Source: AeroStrategy

4.3. Cost Structure

There are three primary cost elements in engine overhaul: material, labor and repair/specialty services (*Figure 4.6*).

- Material** – The largest driver of engine overhaul cost is material/parts, accounting for 62 percent of the total. Material includes new OEM new replacement parts, life limited parts (typically disks and rotors), used/serviceable parts, and PMA parts. Regardless of who performs the MRO service (operator, independent or OEM), all will use parts acquired from the OEM. In order to reduce costs, airlines may also use used/serviceable parts and PMA parts in-lieu of OEM parts.
- Labor** – Labor is the second largest cost item at 22 percent of the total outlay. Labor includes direct labor to disassemble, inspect, repair or replace, reassemble and test the engines. It also includes general and administrative overhead and employee benefits. Globally, there are 217,376 technicians in the engine overhaul supply chain, around 26 percent of whom are FAA-certificated mechanics or repairmen. In the United States there are 95,272 technicians – approximately 54 percent or 51,432 are FAA-certificated mechanics or repairmen. The percentage of certificated technicians varies by the type of overhaul facility. For dedicated engine overhaul facilities, approximately 10 percent of the technicians are FAA-certificated compared to an airline engine overhaul shop where 80-90 percent of the technicians are FAA-certificated.
- Repair/Specialty Services** – Overhaul providers, where possible, seek to repair engine parts rather than purchasing new parts. These repairs may be contracted to independent or specialized shops. A good example is turbine blade repair.

Figure 4.6
Engine Overhaul Cost Structure



Source: AeroStrategy

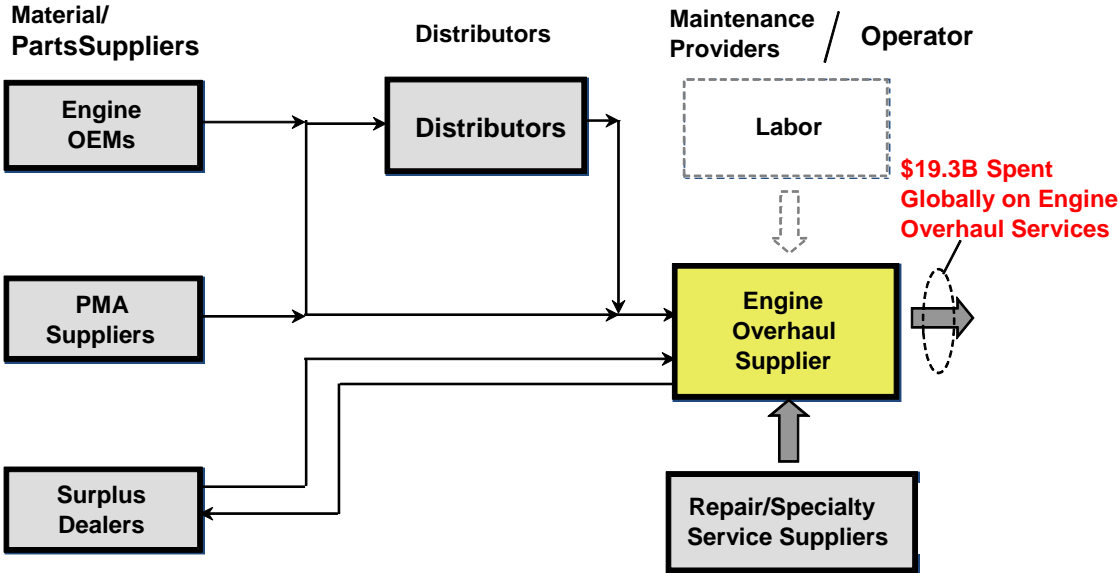
4.4. Supply Chain

There are four main sources of supply to engine overhaul shops (*Figure 4.7*): material/part suppliers, distributors, repair/specialty service suppliers, and labor (the latter is internal to the engine overhaul shop).

- Material/Parts Suppliers** – Material suppliers include engine OEMs, PMA holders and surplus dealers. Approximately 60 percent of engine OEMs are domiciled in the United States – these include GE, Pratt & Whitney, Honeywell and Williams International; 38 percent of the engine OEMs are domiciled in Europe – these include Rolls-Royce, SNECMA and Turbomeca. The largest PMA holders include HEICO, Chromalloy, BELAC and Wencor; these suppliers represent approximately half the PMA market and are all domiciled in the United States. There are hundreds of smaller, lower tier suppliers that represent the remaining PMA market. Key engine surplus dealers include OEMs - GE and Pratt & Whitney. Other major surplus dealers are AAR, Airliance, GA Telesis and Aeroturbine. Approximately two-thirds of surplus dealers are domiciled in the United States. On average, engine overhaul providers work with 10-20 material suppliers including OEMs, PMAs and surplus dealers.
- Distributors** – Material/parts suppliers can sell directly to the engine MRO provider or through a distributor. Engine OEMs typically sell directly – the exception being materials and parts for old, declining product lines, which may be sold through a distributor like Aviall. First and second tier PMA holders also sell direct; third tier PMA holders typically utilize distributors or first/second tier PMA holders for distribution. Surplus dealers tend to sell directly to engine overhaul shops. The largest distributor is Aviall with approximately a third of the market. There are a dozen secondary distributors like Satair, B/E Aerospace and Wesco that represent the other third; the remaining market is represented by 40-50 tertiary distributors. Over 60 percent of distributors are domiciled in the United States. On average, engine overhaul providers work primarily with four or five major distributors and a dozen or so smaller distributors – mostly for obtaining hardware and consumables.

- Repair/Specialty Services** – Engine OEMs like GE and Pratt & Whitney are key repair/specialty service providers, as are large airline third-party engine MRO providers like Lufthansa Technik and SR Technics. The largest independent provider is Chromalloy; other notables include PAS Technologies, Sermatech and GKN Chemtronics. Over half of the repair/specialty service providers are domiciled in the United States, although many of them have facilities all over the world due to the importance of turn-around time for repair/specialty services. For example, Pratt & Whitney has three facilities in Singapore as well as in Taiwan, Ireland and Mexico. On average, engine overhaul providers work with 20-30 FAA-certificated repair/specialty service providers of parts repair and four or five non-FAA-certificated suppliers of services like machining and plating. Engine overhaul providers focused on BGA utilize a smaller number of outside providers with approximately 10-12 repair/specialty service shops.

**Figure 4.7
ENGINE OVERHAUL SUPPLY CHAIN**



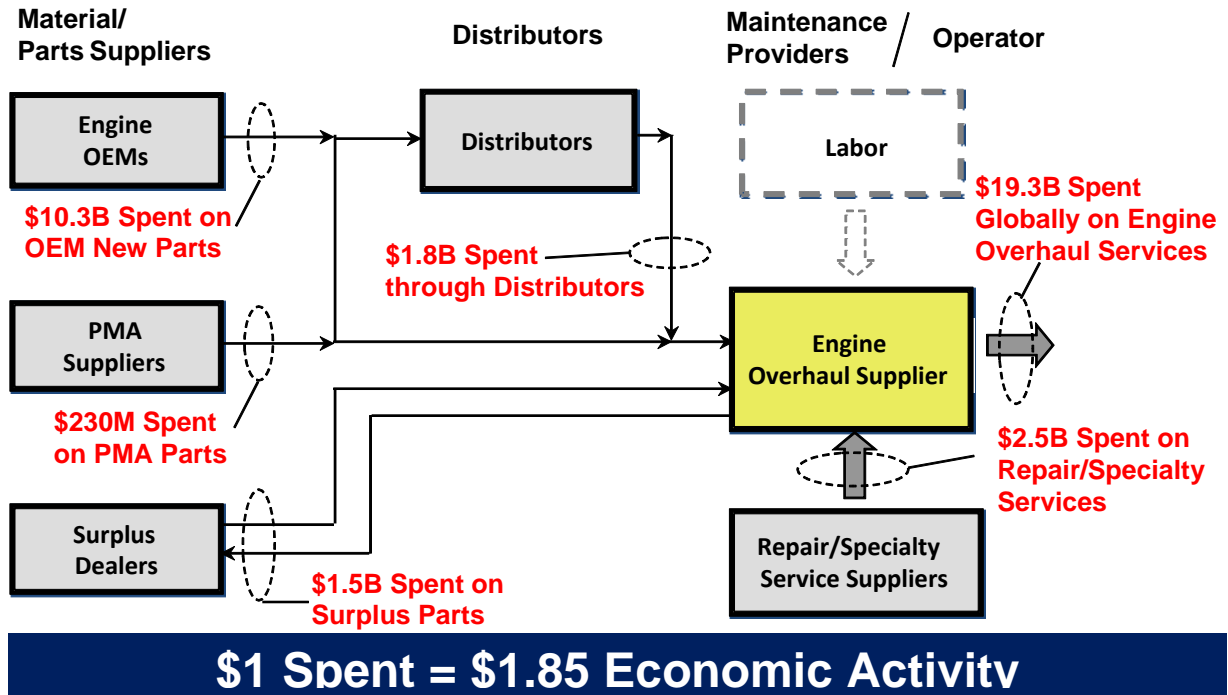
Source: AeroStrategy

4.5. Economic Activity

Globally, operators spend \$19.3B on engine MRO services which generates \$35.6B in overall economic activity in the supply chain (Figure 4.8). For every dollar spent on engine overhaul services, an additional \$1.85 in economic activity is generated. Of the \$35.6B of global economic activity, the United States generates \$19B (Figure 4.9). Engine MRO material consumption is the largest economic activity outside of engine overhaul service; over \$12B per year is spend on material globally and over 60 percent is with suppliers domiciled in the United States (or approximately \$7.4B annually). Repair/specialty service and distribution generate \$2.5B and \$1.8B respectively, approximately 60 percent with companies domiciled in the United States.

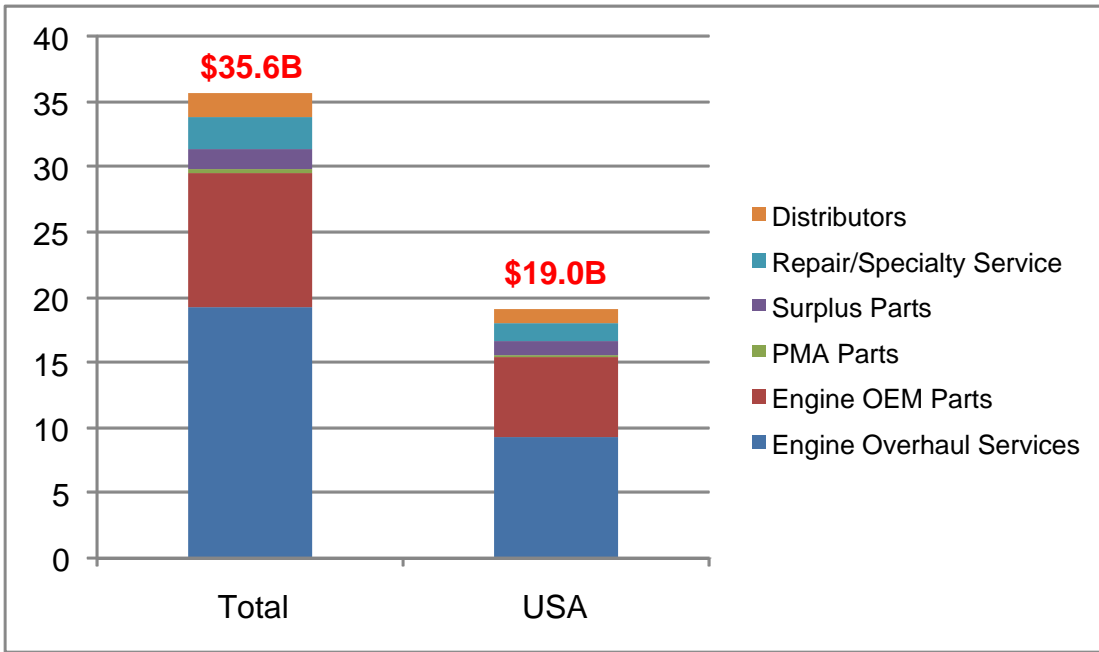
The global engine overhaul supply chain employs 332,980 workers within 1,970 suppliers (Figure 4.10); approximately 70 percent of the suppliers are SMEs, employing nearly 21,000 people worldwide. In the United States, there are 123,524 employees in the engine overhaul supply chain within 1,653 suppliers; nearly 80 percent of the suppliers in the United States are SMEs – employing nearly 19,000 people.

Figure 4.8
Economic Activity Generated By Engine Overhaul



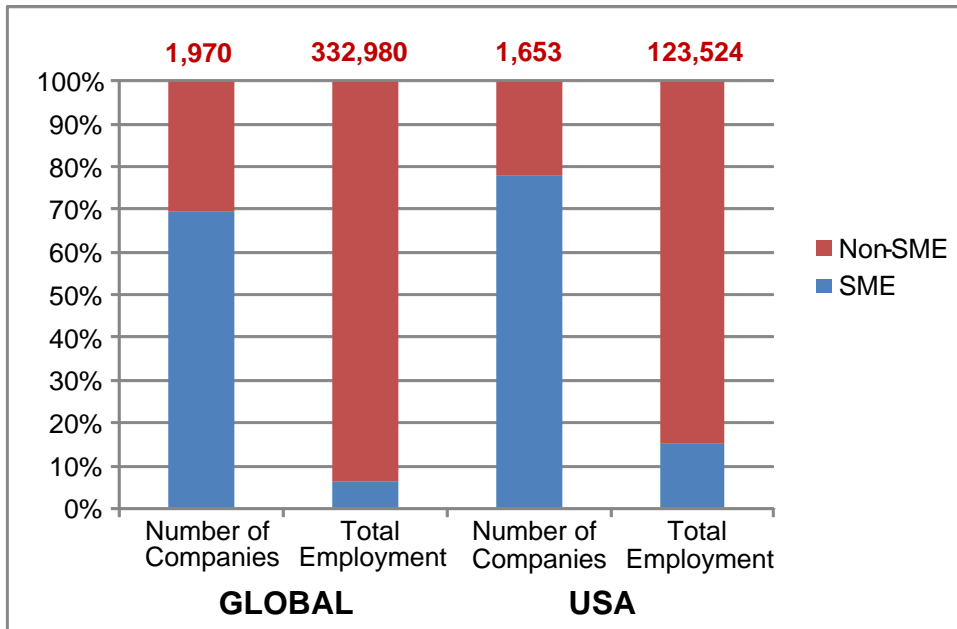
Source: AeroStrategy

Figure 4.9
U.S. ROLE IN THE ENGINE OVERHAUL SUPPLY CHAIN



Source: AeroStrategy

Figure 4.10
ENGINE OVERHAUL EMPLOYMENT



Source: FAA

5. COMPONENT MAINTENANCE

5.1. Introduction

Aircraft components provide the basic functionality for aircraft flight, including aircraft control & navigation, communications, control surface movement, cabin air conditioning, electrical power, and braking.

A typical air transport aircraft has hundreds of components from dozens of manufacturers. Accordingly, the component MRO market is extremely fragmented. *Figure 5.1* details the major market segments.

Figure 5.1
AIR TRANSPORT MARKET - COMPONENT MRO SEGMENTS

Market Segment	Maintenance Activities	Percent Component MRO Costs
Wheels & Brakes	Overhaul, repair or replacement of brake pads, wheel, antiskid and servovalves	17%
Avionics	Overhaul, repair or replacement of displays, communications equipment, navigation systems, and autopilot	15%
Auxiliary Power Unit	Overhaul or repair of the auxiliary power unit including accessories	13%
Fuel Systems	Overhaul, repair or replacement of engine fuel controls and airframe fuel systems	8%
Hydraulic Power	Overhaul, repair or replacement of hydraulic pumps and conveyance hardware	4%
Flight Controls	Overhaul, repair or replacement of primary and secondary flight control actuators	8%
Thrust Reversers	Overhaul, repair or replacement of aircraft's thrust reversers, including actuation and surfaces	5%
Landing Gear	Overhaul, repair or replacement of aircraft's landing gear systems	4%
Electrical	Overhaul, repair or replacement of electrical generation and distribution systems	4%
Other	Overhaul, repair or replacement of a myriad other systems including environmental control, in-flight entertainment, safety, water & waste, and pneumatics	22%

Source: AeroStrategy/OAG Aviation

Wheels and brakes are typically the largest category of component maintenance spending on most aircraft, accounting for 15 to 20 percent. This is attributable to the significant wear and tear from an aircraft's multiple landings as well as the exotic materials such as carbon composite brake pads that are light-weight with heat dissipation properties.

Flight deck avionics is the second largest component MRO category. Avionics are comprised of several major subsystems including cockpit displays, communications equipment, navigations systems, and autopilot. Dozens of “black boxes” are required. Avionics account for 15 percent of a typical aircraft’s component maintenance costs; the percentage is even higher for business jets.

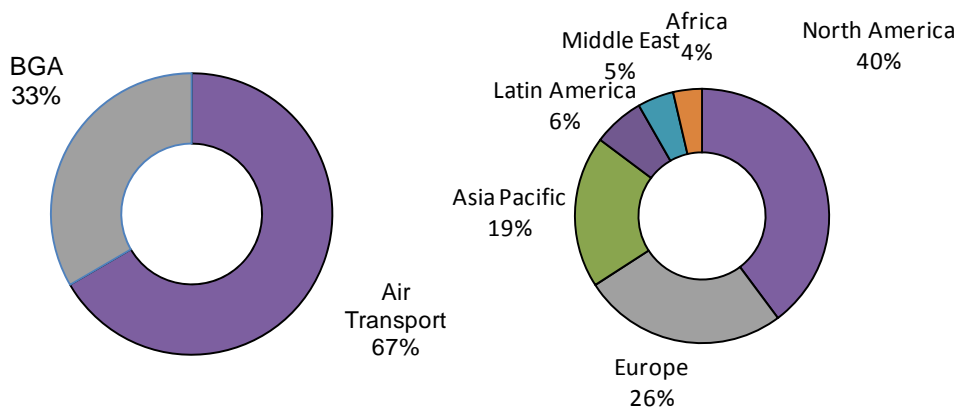
The third largest component maintenance category is auxiliary power unit (APU) maintenance. The APU is a gas turbine engine, which provides electric power, engine starting and cabin cooling functionality.

Beyond these three major categories are several important maintenance segments: fuel systems (eight percent of total component maintenance spending), flight controls (another eight percent), thrust reversers (five percent), hydraulics (four percent), electrical systems (an additional four percent), and landing gear (another four percent).

5.2. Market Description

The civil component MRO market is as estimated \$12.2B. Air transport is the largest market segment at \$8.1B or 67 percent of the total market with BGA the remaining third.

Figure 5.2
2008 GLOBAL CIVIL COMPONENT MRO MARKET (\$12.2 BILLION)



Source: AeroStrategy/OAG Aviation

Forty percent of component MRO demand originates from aircraft operators in North America. Europe is the second largest market (26 percent), followed by Asia-Pacific (19 percent), Latin America (six percent), Middle East (five percent) and Africa (four percent).

There are four types of firms performing component MRO activities:

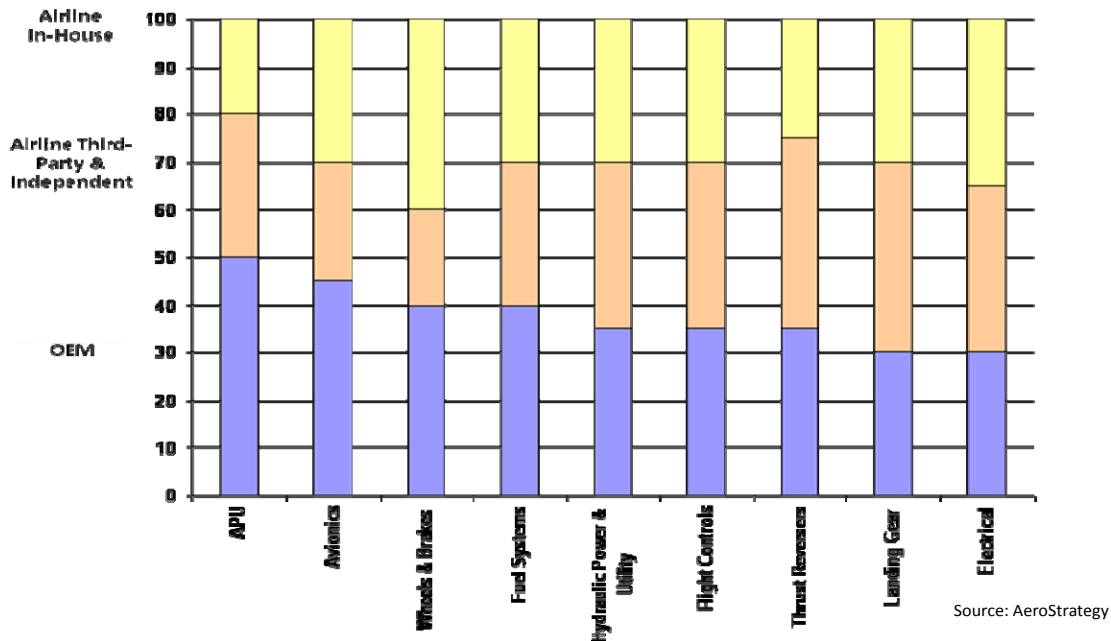
- **OEMs** – Component OEMs are major players in the component MRO market. Beyond basic repair activities, OEMs also sell replacement parts and refurbish piece

parts. The OEMs include: Honeywell, Goodrich, Hamilton Sundstrand, Rockwell Collins, Thales, SAFRAN, Parker Aerospace, GE Aviation, Eaton Aerospace, Meggitt, Woodward, Zodiac, Liebherr, and B/E Aerospace. Most OEMs focus exclusively on maintenance of their own equipment.

- **Operator** – This group includes airlines with in-house component maintenance capability. Major airlines in this category include United, American, Delta, British Airways, Air France/KLM, Japan Airlines and Lufthansa.
- **Airline Third Party.** Often an airline’s internal operations provide third-party MRO services to improve revenues and margins. Major airlines that provide services to third parties include Delta TechOps, Lufthansa Technik, Air France/KLM Engineering, Singapore Airlines Engineering Company, United Services, HAECO (same parent company as Cathy Pacific).
- **Independent** – There are numerous independent providers serving the global market including SR Technics, ST Aerospace, Aveos, Triumph, AAR, Aviall and NORDAM.

MRO market shares of each category reflect the underlying economics of the maintenance activities as well as the competitiveness of each provider group.

Figure 5.3
2008 COMPONENT MRO MARKET SHARES BY SUPPLIER CATEGORY



Overall, operators perform approximately 30 percent of component MRO activities. Component OEMs have a slightly larger share (35 percent), and they control approximately half of the market for APUs and avionics. Airline third party shops and independents make up the remaining 35 percent of the market.

The component MRO market is indeed global, as most components are relatively easy to package and ship to a global base of users. The intra-region flow is also shaped by the location of providers. The United States has the highest density of component OEMs and, by AeroStrategy estimates, has a 55-60 percent share of the installed components. As a result, the United States has a deep concentration of OEM MRO service centers. In contrast, Europe has many leading component OEMs as well as a very strong base of airline third-party and independent MROs such as Lufthansa Technik, SR Technics, and Air France/KLM. As a result, North American and European suppliers are both net exporters of component MRO services.

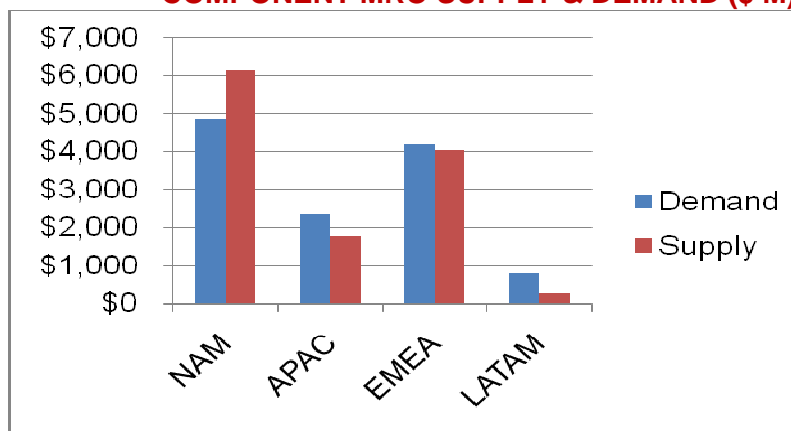
Figures 5.4 and 5.5 demonstrate that the North American market is a net exporter of \$1.2B in component MRO; in-region operators generate an estimated \$4.9B of the demand while in-region providers capture \$6.1B of the revenue. All other regions are net importers of component MRO services.

Figure 5.4
COMPONENT MRO INTRA-REGION FLOW

Market Segment	Demand By Operator Region		Provider Region			
			NAM	APAC	EMEA	LATAM
Air Transport	NAM	\$2,876M	80%	4%	15%	1%
	APAC	\$1,941M	20%	70%	10%	0%
	EMEA	\$2,891M	15%	5%	80%	0%
	LATAM	\$426M	50%	2%	15%	33%
BGA	NAM	\$1,993M	93%	1%	5%	1%
	APAC	\$421M	60%	25%	14%	1%
	EMEA	\$1,295M	37%	1%	60%	2%
	LATAM	\$368M	60%	1%	25%	14%

Source: AeroStrategy

Figure 5.5
COMPONENT MRO SUPPLY & DEMAND (\$ M)



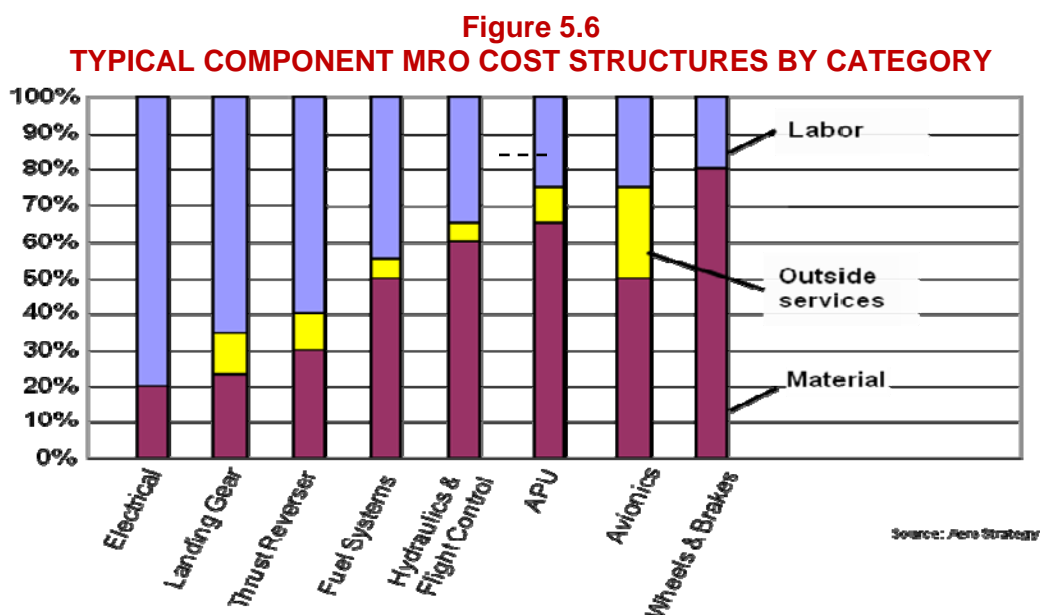
Source: AeroStrategy

5.3. Cost Structure

The cost structure of component maintenance varies considerably by component type and as with engine maintenance, the three major cost elements are: material, labor and repair/specialty services.

- **Material** – The material in component MRO is made up of replacement parts from OEMs, surplus dealers and PMA holders as well as hardware obtained from distributors. OEMs generally have a very high market share for replacement parts – typically 90 percent or more – but for older, mature equipment with significant surplus parts availability, OEM market shares can be less than 70 percent. Usage of PMA parts for component maintenance, currently two percent overall, continues to expand.
- **Labor and Repair/Specialty Service** – Labor is required to inspect, disassemble, repair or replace parts, reassemble and test components. A typical component MRO facility will have a 50:50 mix of FAA-certificated and non-certificated technicians. Repair/specialty services include processes such as maintenance of piece parts, e.g. blades and avionic cards, as well as plating, coating, and machining.

The cost structure of major component categories is shown in *Figure 5.6*. The most labor intensive activities are shown on the left hand side of the chart including electrical power, landing gear, thrust reverser, and fuel systems maintenance activities; the least labor intensive include wheels and brakes, avionics, and APUs; all of these categories are heavily dependent on material and repair/specialty services. Overall, labor is approximately 35 percent of component MRO spending; materials 60 percent, and outside services 5 percent.



The cost structure can be influenced by the supplier type. OEMs generally prefer to maximize usage of their own materials/parts in lieu of alternate material sources and labor. In contrast, independent MRO providers seek to minimize purchases of materials and parts from OEMs. Where possible, independents will develop repairs for parts by using designated engineering representatives (DER). Most believe that part repair capability increases margins and enhances operational control by reducing dependency on OEM part availability.

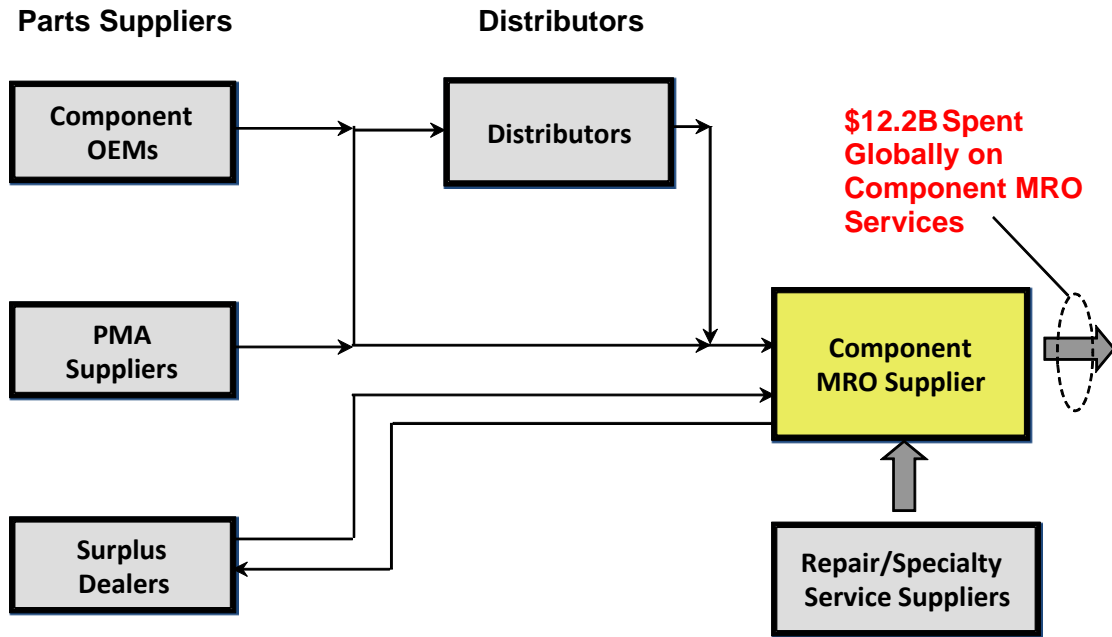
5.4. Supply Chain

There are several important categories of suppliers to component MRO: material/parts suppliers, distributors, and repair/specialty service providers.

- **Material/Parts Suppliers** – Material/part suppliers include component OEMs (including hardware manufacturers), PMA holders and surplus dealers. Approximately 60 percent of component OEMs (the largest are cited in paragraph 5.1) are domiciled in the United States. Major PMA holders include HEICO, Chromalloy, BELAC, Wencor, and ACS; in addition there are hundreds of smaller PMA holders. The vast majority of PMA firms are based in the United States. Finally, there are dozens of surplus dealers supporting the component MRO supply chain; major dealers include AAR, Airliance, GA Telesis, Volvo Aero, Kellstrom, GECAS, Pratt & Whitney, Unical, AJ Walter, and Aeroturbine. Approximately two-thirds of surplus dealers are domiciled in the United States.
- **Distributors** – Like the engine overhaul supply chain, major part/material suppliers sell directly to MRO shops while smaller suppliers typically sell through distributors. Distributors typically sell hardware, consumables and replacement parts made by smaller OEMs. The largest distributor is Aviall with approximately a third of the distribution market. There are a dozen secondary distributors like Satair, BE Aerospace and Wesco that represent the other third and the remaining market is represented by 40 to 50 tertiary distributors. Over 60 percent of distributors are domiciled in the United States.
- **Repair/Specialty Service** – There are thousands of specialty service providers that support component MRO activities with services ranging from piece part maintenance to plating, machining, coating, brazing, and inspection. AeroStrategy believes that 50 to 60 percent of these suppliers are based in the United States.

The number of suppliers that support an individual component MRO facility varies greatly; a facility focused on a narrow product range might deal with 20-40 suppliers, while a facility servicing a broad range of components will have a supplier base in excess of 100 entities.

**Figure 5.7
COMPONENT MRO SUPPLY CHAIN**

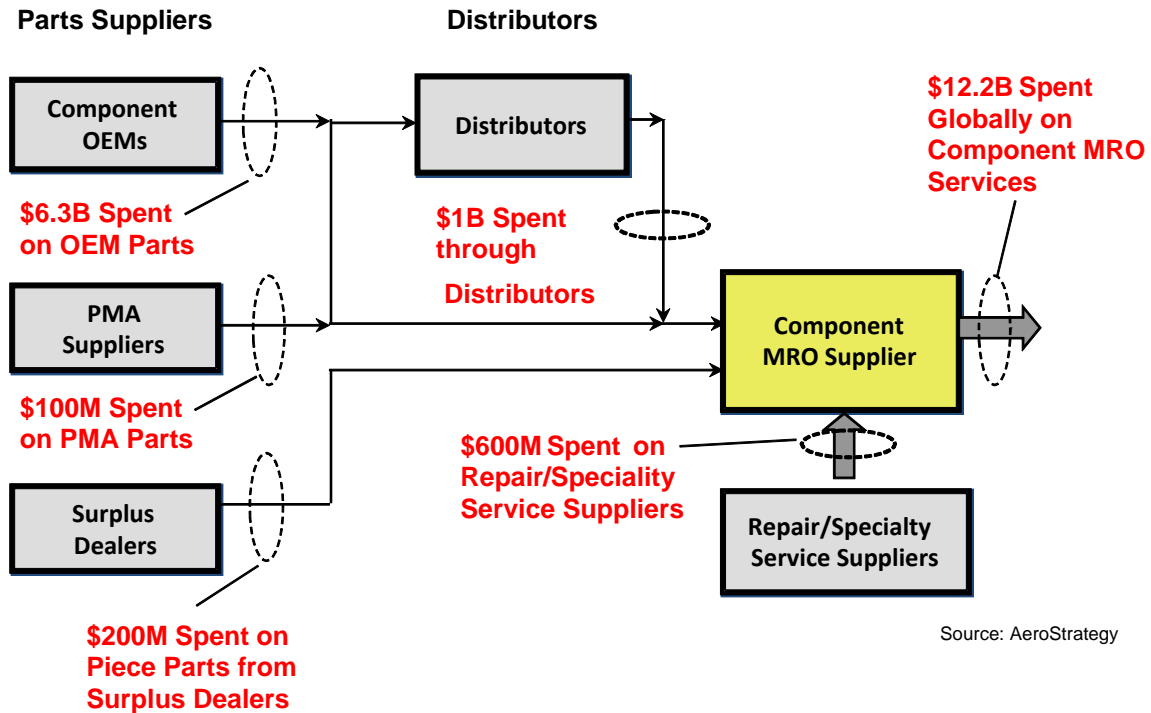


Source: AeroStrategy

5.5. Economic Activity

Globally, operators spend \$12.2B on component MRO services which generates \$20.3B in overall economic activity in the supply chain. Beyond the \$12.2B accrued by MRO facilities, there is another \$6.3B spent on material/parts from OEMs, \$1B from distributors, \$600M from repair/specialty providers, \$200M from surplus dealers, and \$100M from PMA parts suppliers. In aggregate, every dollar spent on component MRO services generates about \$1.67 in economic activity.

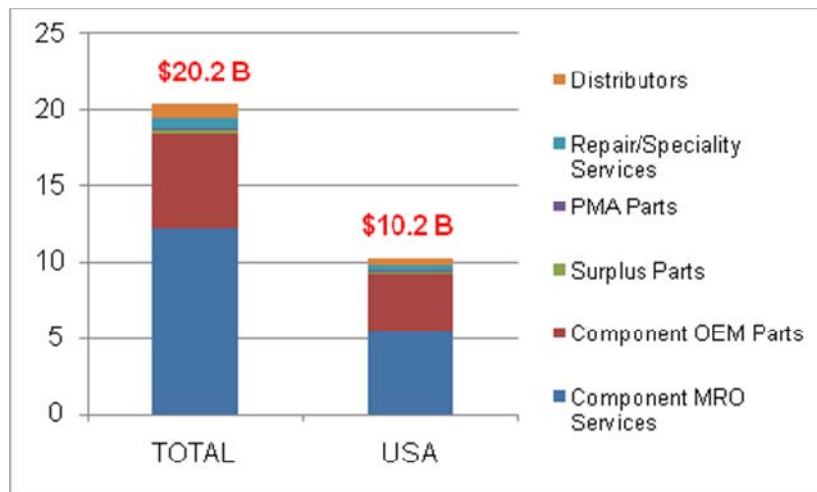
**Figure 5.8
ECONOMIC ACTIVITY GENERATED BY ENGINE COMPONENT MRO**



\$1 Spent = \$1.67 Economic Activity

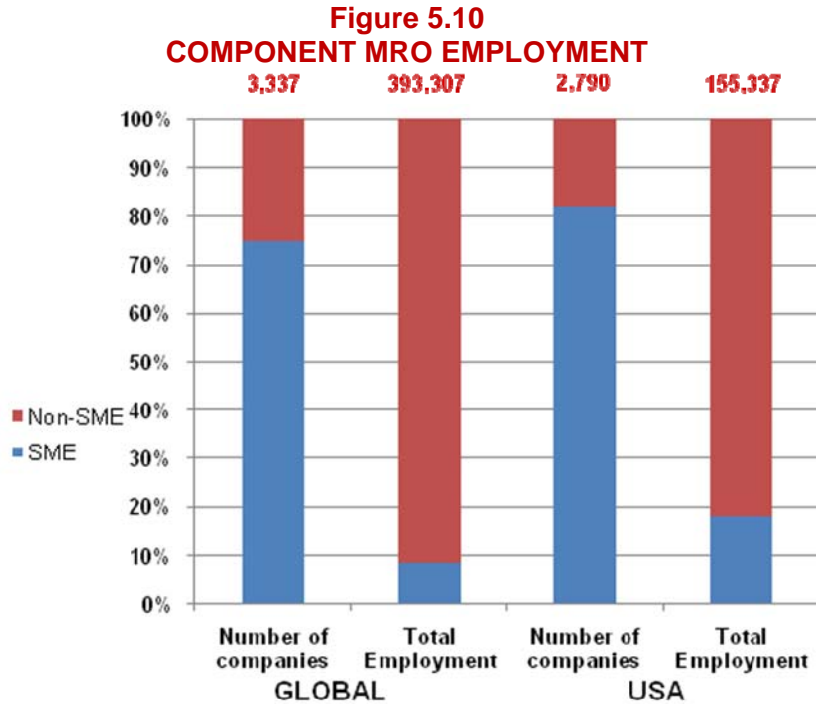
The U.S. plays a prominent role in component MRO activity (Figure 5.9) because of its large air transport and BGA fleets and its high concentration of component OEMs. Overall, U.S. suppliers account for an estimated \$10.2B of the \$20.2B in total economic activity – 50 percent of the total.

**Figure 5.9
ROLE OF U.S. IN THE COMPONENT MRO SUPPLY CHAIN**



While difficult to estimate with precision, there are nearly 400,000 employees within more than 3,300 firms worldwide participating in component MRO activities. Seventy-five percent of firms are SMEs.

In the United States, there are nearly 2,800 firms with more than 155,000 employees in the component MRO market. SMEs make up 80 percent of all firms and account for 20 percent of all employees.



Source: FAA

6. LINE MAINTENANCE

6.1. Introduction

Line Maintenance includes light, regular checks that ensure the aircraft is fit for flight, trouble shooting, defect rectification, and component replacement. Technicians diagnose and correct issues on the aircraft and carry out these checks on an ad-hoc basis or scheduled interval. Line maintenance consists of three primary activity categories: Transit checks, daily/weekly checks and A-checks. Historically, line maintenance included B-checks, which rarely exist these days; the associated maintenance activity is typically captured in A and/or weekly checks. For BGA, line maintenance is captured in airframe heavy maintenance (Section 3).

Table 6.1
LINE MAINTENANCE OVERVIEW

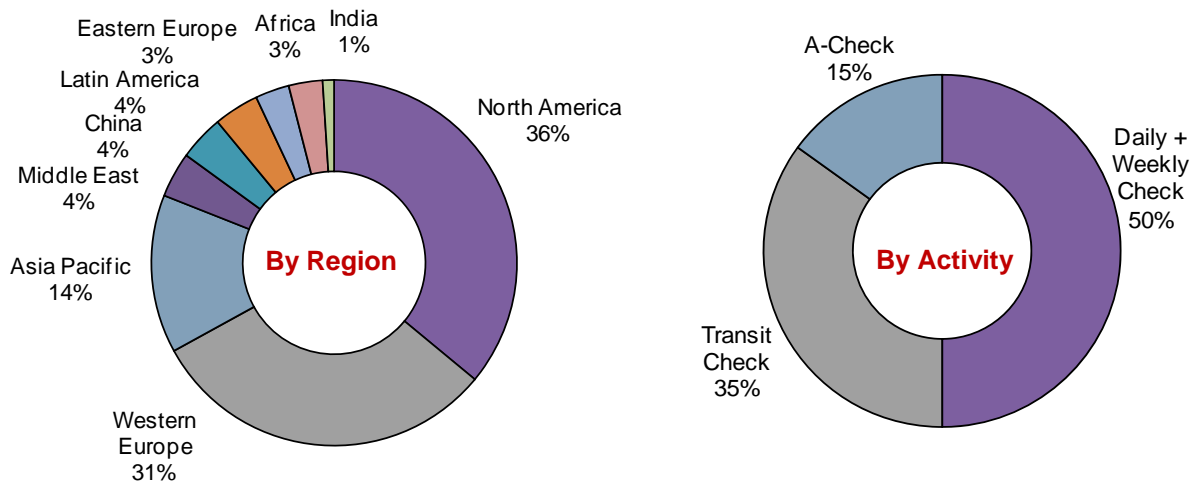
Activity	Description	Frequency	Labor Input	Typical Cost
Transit checks	<ul style="list-style-type: none"> • Sometimes described as turn-round checks • Consists of specific visual checks (“walk-round”), review of check log and defects, and where needed, defect rectification and trouble-shooting • For long-haul operations, it will include tasks for twin-engine operation (ETOP) clearance 	Every flight cycle	1 – 4 labor hours	\$75 to \$350 per flight cycle
Daily/Weekly checks	<ul style="list-style-type: none"> • Sometimes described as overnight checks • Also include 7/8 day checks and 3/4 day checks • Routine work as well as tasks specified by the maintenance planners, e.g., defect rectification, out-of-phase checks • Increasingly it is also used for In-Flight Entertainment (IFE) and cabin maintenance 	Every 24 to 36 hours (occasionally 48 hours) Every 4 to 8 Days	Daily: 5 -10 labor hours Weekly: 10 – 30 labor hours	\$150 to \$500 per day
A-checks	<ul style="list-style-type: none"> • Usually conducted at a few main bases within the airline network • Routine work as well as tasks specified by the maintenance planners, e.g., defect rectification, out-of-phase checks • Increasingly this downtime is also used for IFE and cabin maintenance 	Regional: Between 350 to 450 Flight Hours Narrowbody & Widebody: Between 500 to 700 Flight Hours	Regional: 50-100 labor hours Narrowbody & Widebody: 100-250 labor hours	\$15 to \$40 per flight hours

Source: AeroStrategy

6.2. Market Description

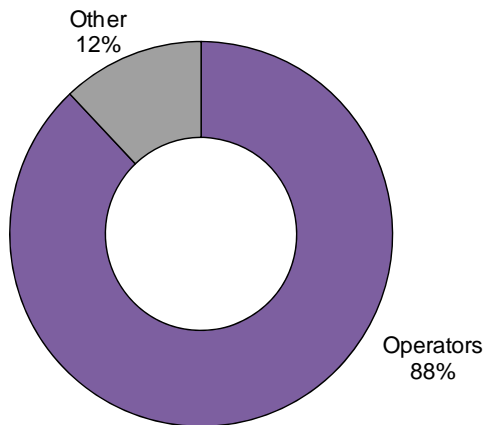
The civil line maintenance market is estimated to be \$9.6B. The daily/weekly check is the largest segment at half of the market followed by transit checks and A-Checks. On a regional basis, North America is the largest market, generating \$3.4B of the total demand, followed closely by Europe (Western and Eastern) at \$3.2B. Asia Pacific, including India and China, is the third largest market, estimated at \$1.9B.

Figure 6.2
2008 WORLD LINE MAINTENANCE MARKET (\$9.6 BILLION)



Source: AeroStrategy/OAG Aviation

Figure 6.3
2008 LINE MAINTENANCE PARTICIPANTS



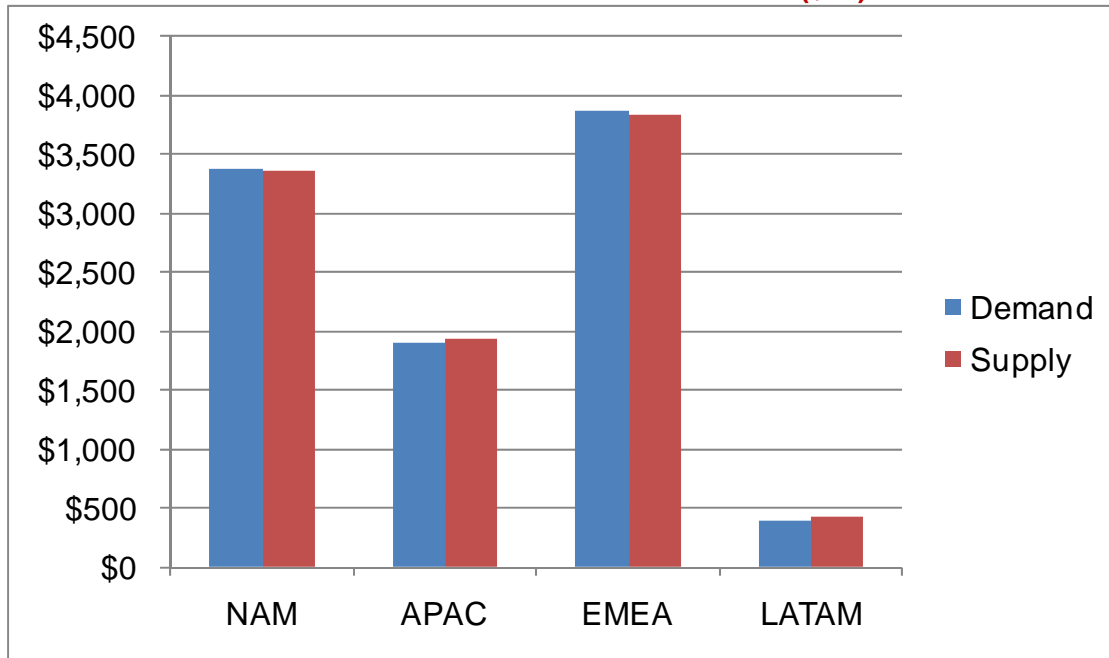
Source: AeroStrategy

Nearly 90 percent of line maintenance is performed by operators. Line maintenance is seen as critical to on-time performance and therefore part of the airlines' "core business". There is often a lack of an alternative and competitive provider base. Only 10 to 15 percent of line maintenance is contracted to an outside provider. When airlines do use contract maintenance, it is typically at airports where they do not have the presence to justify a dedicated line station; high growth, low volume international airlines. MROs are more likely to be used for contract line

maintenance in order to manage growth; this is particularly the case for new stations with little volume or experience, or requiring quick implementation. Key contract line maintenance providers include airline third party MROs like Lufthansa Technik, United Services and SR Technics and independents like Certified Aviation Services.

North American operators generate \$3.39B (Figure 6.4) of line maintenance demand – 98 percent of the line maintenance is performed by providers domiciled in North America (Figure 6.5); An additional \$52M of line maintenance is done in North America for airlines domiciled in other regions – resulting in a total of \$3.36B for North American line maintenance suppliers. EMEA operators generate \$3.9B of line maintenance demand – 98 percent of which is domiciled in EMEA. Thus, North America has neither a positive or negative balance of trade in the line maintenance arena.

Figure 6.4
LINE MAINTENANCE SUPPLY & DEMAND (\$ M)



Source: AeroStrategy / OAG Aviation

Figure 6.5
LINE MAINTENANCE INTRA-REGION FLOW

Market Segment	Demand By Operator Region		Provider Region			
			NAM	APAC	EMEA	LATAM
Air Transport	NAM	\$3,387M	97.8%	0.7%	1.1%	0.5%
	APAC	\$1,907M	0.9%	97.9%	1.1%	0.0%
	EMEA	\$3,868M	0.8%	1.0%	97.8%	0.4%
	LATAM	\$395M	0.5%	0.1%	0.4%	99.0%

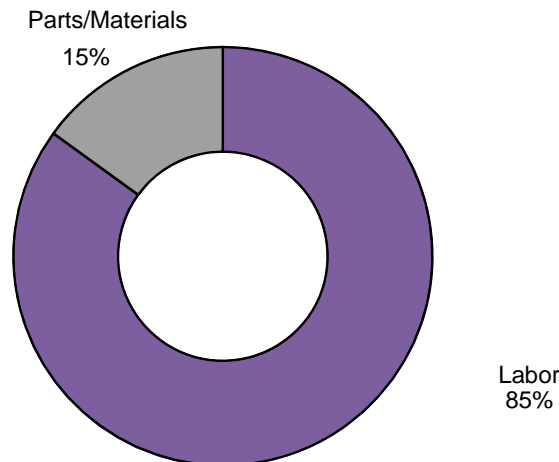
Source: AeroStrategy

6.3. Cost Structure

There are two primary cost drivers in line maintenance (*Figure 6.6*) - labor and material.

- **Labor** – Labor is the dominant component of line maintenance cost, accounting for 85 percent of the total. Labor includes direct labor required to inspect, troubleshoot, removal and replacement of line replaceable units (LRU) and engines as required. Labor cost also includes general and administrative overhead and employee benefits. Over 98 percent of line maintenance technicians are FAA-certificated because line maintenance mechanics need to be able to perform required inspection item inspections and sign aircraft logbooks and/or maintenance releases for the airline.
- **Material** – Material is typically 15 percent of the cost of line maintenance. Material is primarily expendables and consumables, such as fasteners, brackets, solvents, and the like. Note that the airline customer will typically provide the LRU components that may be required.

Figure 6.6
LINE MAINTENANCE COST STRUCTURE



Source: AeroStrategy

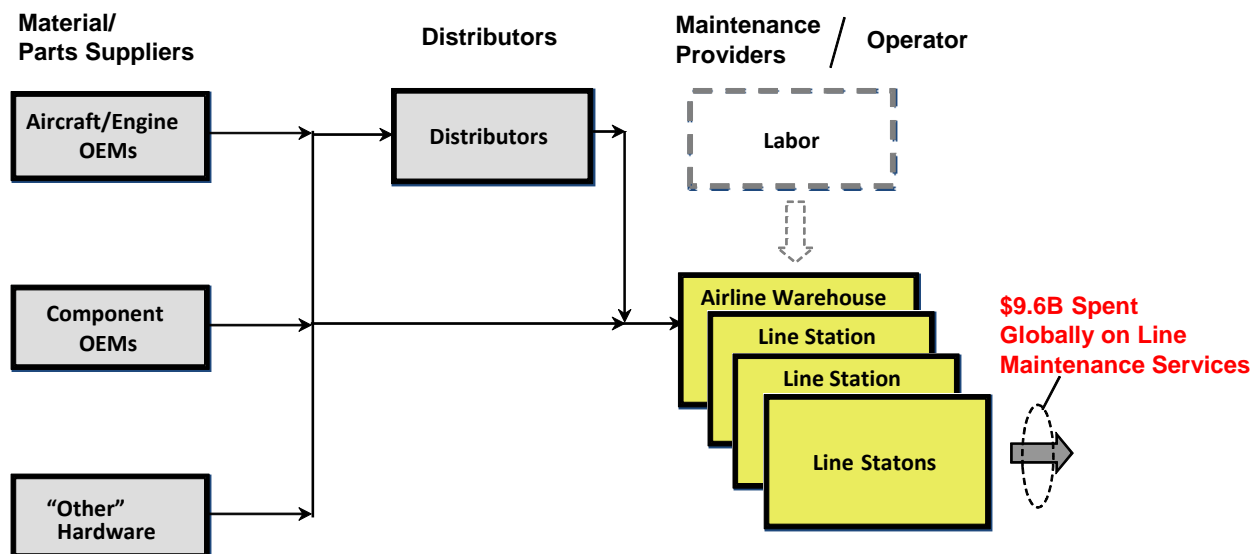
6.4. Supply Chain

There are three main supply sources for line maintenance (*Figure 6.7*): material/part suppliers, distributors, and labor (internal to the facility itself).

- **Material/Parts Suppliers** – There are three primary sources for materials and parts: aircraft OEMs, engine OEMs, and “others”, primarily hardware and consumable suppliers. Hardware or “fasteners” are routinely replaced during line maintenance; two of the largest companies are SPS and Alcoa Fastening Systems. “Other” material dealers include dozens of chemical and solvent suppliers. On average, line maintenance providers work with two to four aircraft and engine OEMs and hundreds of consumable and hardware suppliers.

- **Distributors** – Distributors are a common intermediary between material/parts suppliers and airline warehouses. Key distributors are Aviall, Satair, and Avio Diepen. An estimated 60 percent of distributors are domiciled in the United States. Line maintenance providers typically work with five to six major distributors and a dozen or so smaller distributors for hardware and consumables.

Figure 6.7
LINE MAINTENANCE SUPPLY CHAIN



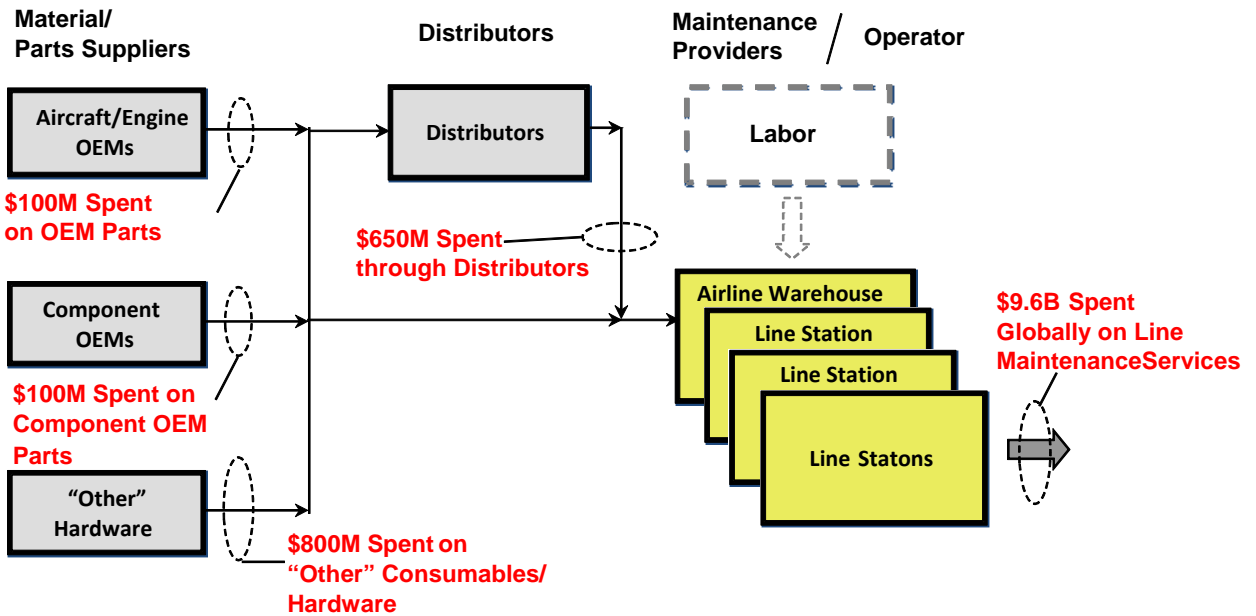
Source: AeroStrategy

6.5. Economic Activity

Globally, operators spend \$9.6B on line maintenance which generates \$11.2B in overall economic activity in the supply chain (*Figure 6.8*). For every dollar spent on line maintenance, an additional \$1.17 in economic activity is generated. Of the \$11.2B of global economic activity, the United States generates \$4.5B (*Figure 6.9*). Labor, which is internal to the line maintenance facility, accounts for approximately 112,400 employees; an additional 9,500 employees support work in other parts of the supply chain. In the United States, there are approximately 46,000 employees in the line maintenance supply chain.

Line maintenance material consumption is the largest economic activity outside of labor; approximately \$1B per year is spent on material globally and approximately 70 percent (\$700M) is spent with suppliers domiciled in the United States. Distribution generates \$650M; approximately 60 percent of suppliers are domiciled in the United States.

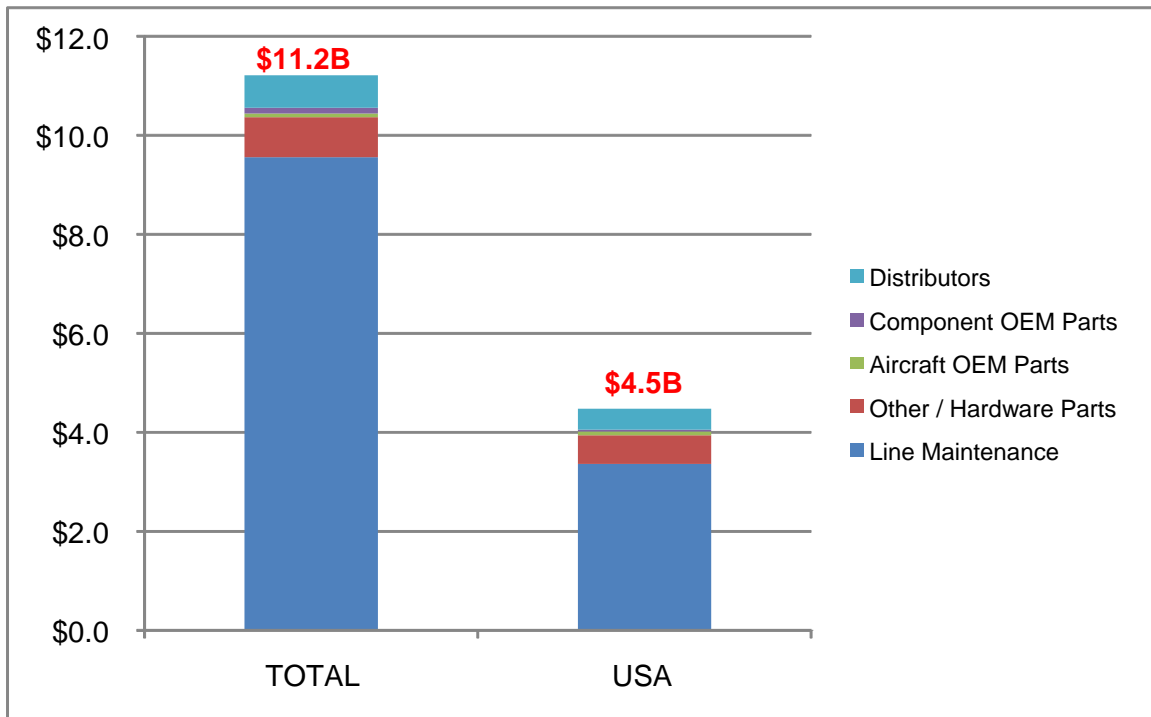
**Figure 6.8
ECONOMIC ACTIVITY GENERATED BY LINE MAINTENANCE**



\$1 Spent = \$1.17 Economic Activity

Source: AeroStrategy

**Figure 6.9
U.S. ROLE IN THE LINE MAINTENANCE SUPPLY CHAIN**

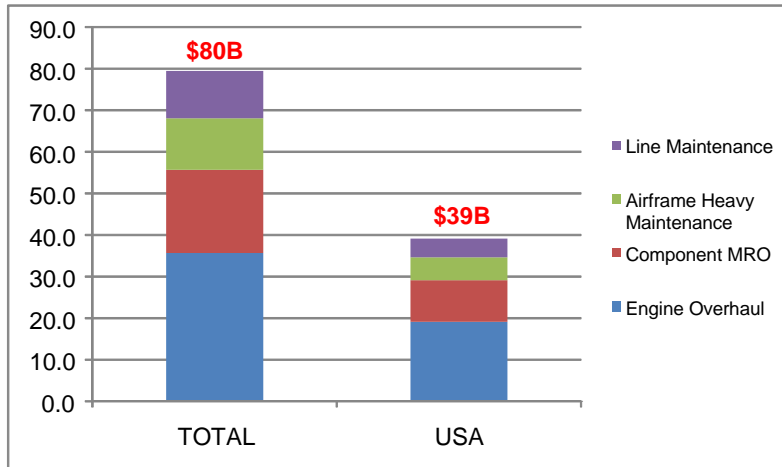


Source: AeroStrategy

7. CONCLUSIONS

In aggregate, the \$50B spent annually on civil aircraft MRO generates \$80B of total economic activity, with the U.S. playing a prominent role (*Figure 7.1*). United States companies account for an estimated \$39B of the total economic activity – nearly 50 percent of the total.

Figure 7.1
U.S. ROLE IN THE CIVIL AVIATION MRO SUPPLY CHAIN

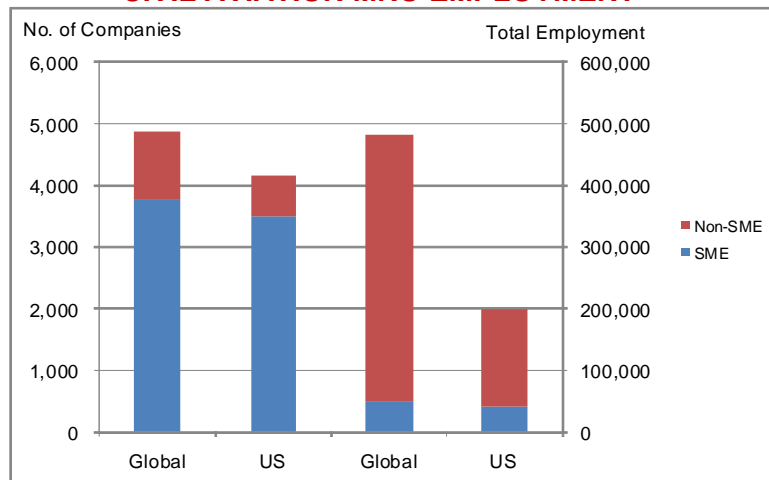


Source: AeroStrategy

There are approximately 480,000 employees within more than 4,800 firms worldwide participating in the civil MRO supply chain (*Figure 7.2*). Nearly 80 percent of these firms are SMEs. Globally, there are over 290,000 technicians – 24 percent of which are FAA-certificated.

In the United States, there are nearly 4,200 firms with more than 200,000 employees in the civil MRO market. SMEs make up 85 percent of all firms and account for 21 percent of all employees. There are over 145,000 technicians in the United States and approximately half are FAA-certificated.

Figure 7.2
CIVIL AVIATION MRO EMPLOYMENT



Source: AeroStrategy