



Offshoring of Airline Maintenance: Implications for Domestic Jobs and Aviation Safety

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Summary

Airlines outsource maintenance to countries like China and El Salvador to achieve cost savings from the comparatively lower wages and from lower costs to build and maintain repair facilities. In some cases, particularly in China, government investment and other incentives, along with backing from national airlines, have spurred rapid expansion of the foreign aircraft maintenance industry over the past decade. While airline maintenance work outsourced to foreign repair facilities has increased considerably over the past decade, there are no conclusive data indicating that this has directly resulted in the loss of U.S. jobs. Despite increased maintenance outsourcing, the United States continues to maintain a positive trade balance for airline maintenance work, a trend that likely reflects the United States' advanced capabilities on high-value engine and aircraft component work.

While investigative reports and labor union sponsored studies of airline outsourcing practices have been critical of foreign repair facilities, more detailed statistical analysis does not support conclusions that maintenance outsourcing or offshoring has had measurable negative impact on safety, quality control, or reliability. Although some experts believe that safety is being compromised and the regulation and oversight of foreign repair stations needs to be improved, analyses of recent trends do not provide obvious evidence that maintenance outsourcing has adversely affected airline safety.

Specific concerns have been raised regarding the Federal Aviation Administration's (FAA's) limited resources to oversee foreign repair stations, and FAA's extensive reliance on foreign regulators and the airlines to monitor these facilities. Additional concerns have been raised over worker training and qualifications at foreign facilities, the relatively low numbers of workers at these facilities with FAA certification, and the lack of English language skills necessary to read and comprehend maintenance manuals and instructions.

Congress also has been concerned about the adequacy of drug and alcohol testing programs at foreign repair stations that work on U.S. aircraft. In the FAA Modernization and Reform Act of 2012 (P.L. 112-95), it mandated drug and alcohol testing at those locations in a manner consistent with existing bilateral aviation safety agreements and the laws of countries where the repair stations are located. Additionally, the act directed FAA to ensure that foreign repair stations are subject to appropriate inspections consistent with existing U.S. requirements and bilateral air safety agreements; inspect foreign repair stations annually; and carry out independent inspections when warranted by safety concerns.

The United States has continued to maintain a positive trade balance with respect to airline maintenance work. However, future foreign investment in advanced training and technical capabilities related to high-value engine and component repair and overhaul could lead to more direct foreign competition in these areas. While available data do not indicate that offshoring of maintenance work has negatively impacted safety, specific areas for potential improvement include the allocation of FAA inspectors and resources focused on the oversight of foreign repair stations; FAA certification and qualification standards for individuals assigned to supervisory roles at foreign repair stations; and standards or guidelines for English language proficiency and comprehension of written technical materials among foreign repair station mechanics.

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Introduction

The passenger airline industry in the United States has gone through significant changes since deregulation in 1978. In domestic operations, airlines now have almost total freedom to determine which markets to serve and what airfares to charge. Competitive forces, as well as higher fuel prices and changing travel patterns, have placed the industry under financial pressure, as evidenced by numerous mergers and bankruptcies.

To stay competitive and profitable, many airlines have joined alliances to expand their global reach and achieve economies of scale. At the same time, price competition has forced airlines to contain costs. One of the practices aimed at keeping costs competitive is the outsourcing of aircraft maintenance, repair, and overhaul (MRO), either domestically or to foreign countries.¹

The practice of outsourcing aircraft maintenance is not restricted to U.S. passenger airlines. Many foreign airlines and cargo carriers also send maintenance work to outside service providers. This report focuses on U.S. passenger airlines because their outsourcing of maintenance, especially to foreign countries such as China and El Salvador, has generated specific concern among Members of Congress. This report analyzes trends in MRO outsourcing and explains the major factors contributing to them. It then considers safety consequences, employment effects, and regulatory implications of increased foreign maintenance of U.S. passenger aircraft.

U.S. Airlines' MRO Strategies

MRO includes four major types of activities:²

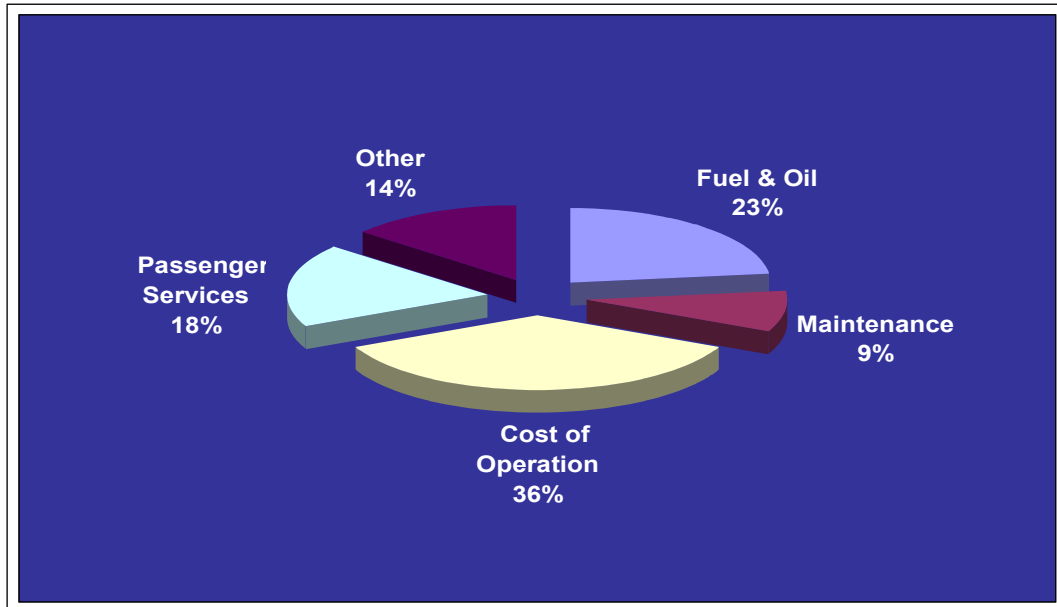
- **Airframe Heavy Maintenance.** A detailed inspection of the airframe and certain components, including any applicable corrosion prevention programs and comprehensive structural inspection and overhaul of the aircraft. Heavy maintenance is comparatively labor-intensive.
- **Engine Repair and Overhaul.** Off-wing repair and replacement of parts to restore the engine to designed operational condition, following guidelines established by the engine manufacturer. Typically, the engine is disassembled and inspected; parts are repaired or replaced as necessary; and the engine is reassembled and tested. Engine MRO requires considerable technological sophistication.
- **Component MRO.** Repair and overhaul of components that provide the basic functionality for air flight, including aircraft control and navigation, communications, cabin air conditioning, electrical power, and braking.
- **Line Maintenance.** Light, regular maintenance checks carried out to ensure that an aircraft is fit for flight. Line maintenance includes troubleshooting, defect rectification, and overnight maintenance.

¹ In this report, MRO (maintenance, repair, and overhaul) and maintenance are used synonymously.

² Aeronautical Repair Station Association (ARSA), "Global MRO Market Economic Assessment," August 21, 2009; Infosys, "Tenets of MRO Strategy for Airlines," December 2007.

According to data reported to the U.S. Department of Transportation (DOT), aircraft maintenance typically accounts for nearly 10% of U.S. passenger airlines' operating costs (see **Figure 1**). The 10 major U.S. passenger airlines reported collective maintenance expenses of \$10.2 billion in 2008 and \$10.1 billion in 2009.³

Figure 1. Major Components of Airline Operating Costs



Source: U.S. DOT Form 41 Airline Operational Cost Analysis Report, International Air Transport Association (IATA), March 2011, p. 12.

Notes: This costs breakdown is based on FY2009 data reported by 10 major U.S. airlines (passenger airlines with annual revenue over \$1 billion). The total operating costs of these major airlines was \$107.5 billion in FY2009.

Prior to 2001, most U.S. airlines performed the majority of their aircraft maintenance work in-house. The percentage of work outsourced, in terms of maintenance dollars, has increased from approximately 20% in 1990 to over 44% in 2011 (see **Figure 2**), according to the Bureau of Transportation Statistics (BTS). According to press reports, Northwest Airlines (before it was acquired by Delta), United Airlines, Delta Airlines, and U.S. Airways all eliminated their in-house heavy maintenance capabilities through bankruptcy restructurings.⁴

Nine major carriers studied by the Department of Transportation's Office of Inspector General (DOT OIG) sent 71% of their airframe heavy maintenance to outside repair stations in 2007, up from 34% in 2003. Foreign repair stations performed 27% of outsourced airframe heavy maintenance in 2007, up from 21% in 2003.⁵ These figures imply that the share of all airframe

³ International Air Transport Association (IATA), "U.S. DOT Form 41 Airline Operational Cost Analysis Report," March 2011, p. 12. The 10 major reporting airlines, in alphabetic order, were Airtran Airways, Alaska Airlines, American Airlines, Continental Airlines, Delta Airlines, Jet Blue Airways, Northwest Airlines, Southwest Airlines, United Airlines, and U.S. Airways.

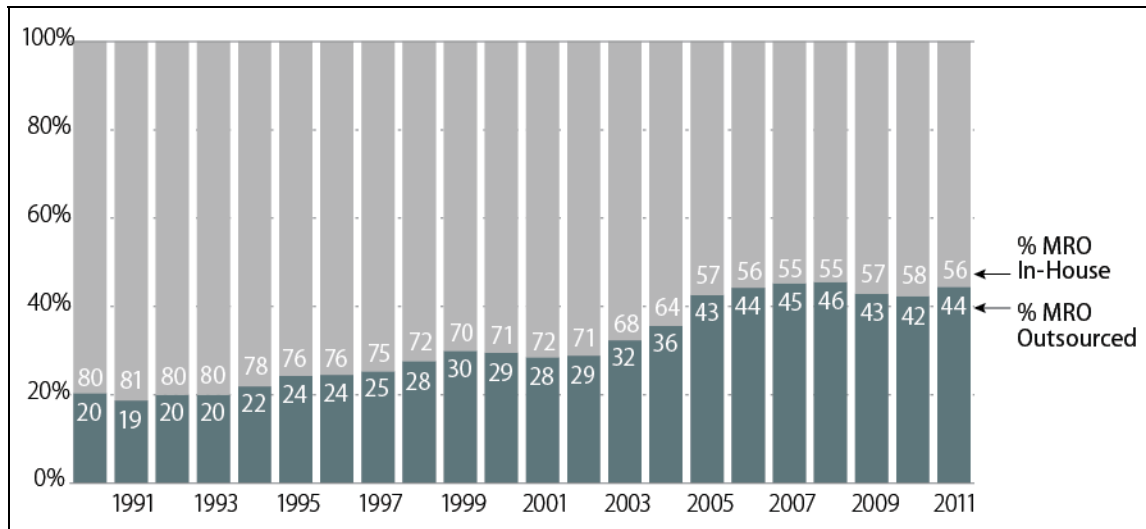
⁴ *USA Today*, "American Airlines to Outsource Some Tulsa Work," October 10, 2011.

⁵ Federal Aviation Administration (FAA), "Air Carriers' Outsourcing of Aircraft Maintenance," Report Number: AV-2008-090, September 30, 2008.

heavy maintenance performed at foreign facilities rose from 7% in 2003 to 19% in 2007. BTS does not have more detailed data on MRO outsourcing, and does not report the shares of outsourced work sent to third-party service providers in the United States as opposed to foreign locations.

Figure 2. Maintenance Outsourced vs. In-House, 1990-2011

Percentage of U.S. Passenger Airlines' Maintenance Expenses

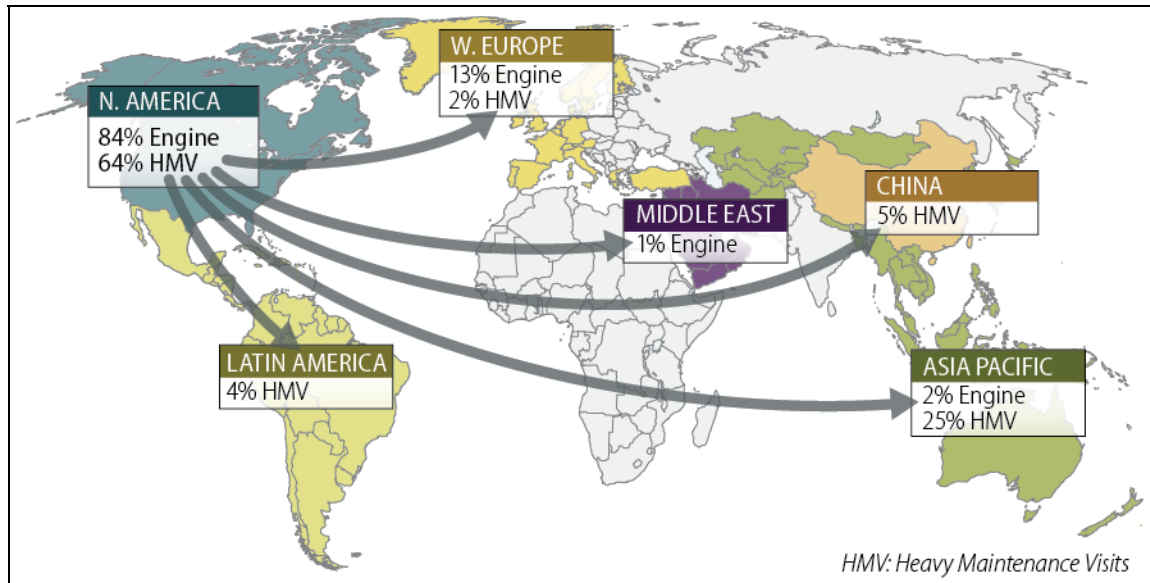


Source: Data provided to CRS by the Bureau of Transportation Statistics (BTS).

Based on research of maintenance contracts, a 2009 presentation by TeamSAI Consulting (the consultancy arm of SAI Engineering, a major MRO provider) indicated that North American MRO outsourcing trends were similar to worldwide behavior:⁶

- a significant amount of heavy airframe and engine work is done by outside MRO providers;
- line maintenance is still mostly kept in-house, but outsourcing is beginning to rise;
- maintenance work that requires significant labor input or capital equipment is more likely to be outsourced;
- the majority of aircraft engine work, which tends to be more technologically demanding, either stays in North America (84%) or is sent to Western Europe (13%), whereas heavy maintenance, which is more labor-intensive, is more likely to be offshored, particularly to Asian and Pacific countries, including China (see **Figure 3**).

⁶ TeamSAI Consulting Services, "Outsourcing Trends in the USA," November 2009.

Figure 3. North American Airlines' Engine and Heavy Maintenance Outsourcing

Source: TeamSAI Consulting Services, "Outsourcing Trends in the USA," November 2009.

The Aeronautical Repair Station Association (ARSA), an industry association, stated in a study that North America was a net provider (exporter) of aircraft MRO services in 2008, with a \$2.4 billion trade surplus. According to ARSA, North America had a positive balance of \$1.4 billion in engine overhaul and a \$1.2 billion positive balance in component maintenance, offset slightly by a small negative balance in heavy airframe MRO.⁷

MRO Outsourcing and Employment

All airlines outsource some of their aircraft maintenance. Some newer carriers have outsourced a large part of their maintenance. Airframe heavy maintenance, which tends to be labor-intensive and requires substantial investments in maintenance facilities and equipment, appears more likely to be outsourced. The share of passenger carrier MRO that is outsourced seems likely to grow, as American Airlines, which has performed most of its maintenance work in-house, is outsourcing some heavy maintenance previously performed at company-owned facilities in Oklahoma and Texas, involving the elimination of approximately 2,000 jobs. Much of this work was transferred to domestic third-party vendors, but some will be performed by HAECO, an MRO based in Hong Kong.⁸

The impact of offshoring of MRO on U.S. employment is unclear. According to BTS data, the number of maintenance jobs at passenger carriers peaked at 72,211 in 2000 and fell to 50,580 in 2011. Over the same period, total employment at U.S. airlines fell from 679,723 to 538,300 (see **Figure 4**). The rate of maintenance employee reduction appears to be in tandem with the decrease

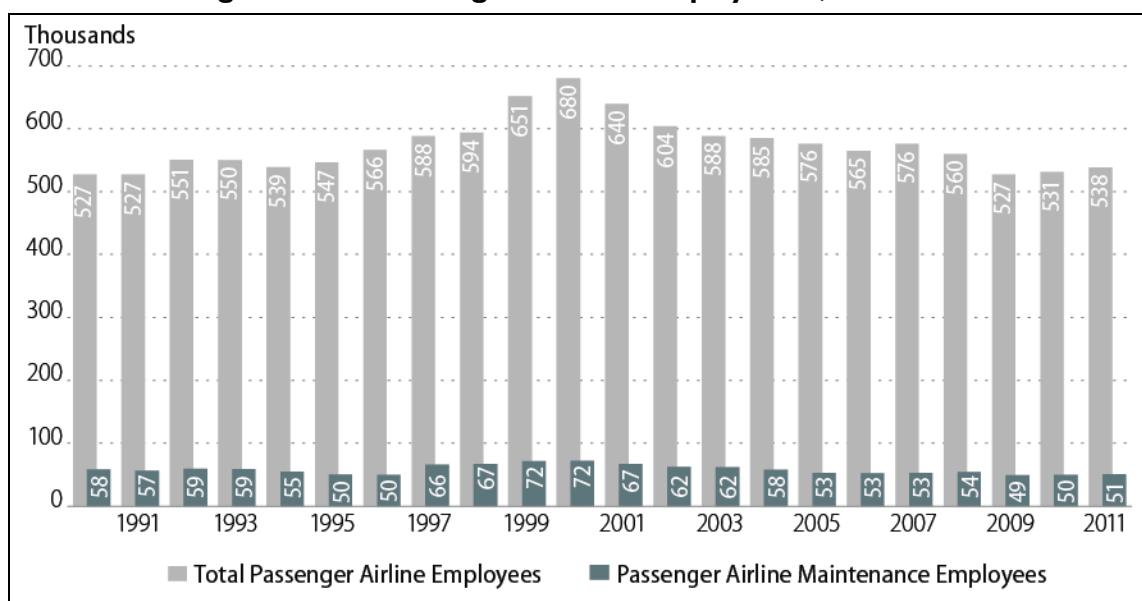
⁷ ARSA, "Global MRO Market Economic Assessment," August 21, 2009, p. 1.

⁸ *USA Today*, "American Airlines to Outsource Some Tulsa Work," October 10, 2011; *Star-Telegram*, "American to Close Alliance Maintenance base by Year's End," September 11, 2012; *Dallas Morning News*, "American Airlines to Close Alliance Maintenance Base by Mid-December," September 10, 2012; *Star-Telegram*, "1000s of American Airlines Workers to Take Buyouts," September 26, 2012.

in total airline employee count, suggesting that airline maintenance workforce reduction seems to reflect the overall employment trend in the passenger airline industry.

Another contributing factor could be that the U.S. commercial air carriers are reducing their fleet size and replacing older and less efficient aircraft with more technologically advanced ones, in the face of uncertain economic conditions and rising fuel prices. The mainline carrier fleet, passenger and cargo aircraft combined, stood at 3,739 aircraft at the end of 2011, 16.7% fewer than in 2000. Meanwhile, the regional carriers continue to reduce their fleet of 50-seat and smaller aircraft. In 2011, the regional carrier fleet was reduced by 46 units to 2,567 units, its lowest level since 2003.⁹

Figure 4. U.S. Passenger Airlines' Employment, 1990-2011



Source: Data provided to CRS by BTS.

From 1990 to 2011, airline maintenance workers accounted for about 10% of the total workforce in the passenger airline industry, in a fairly consistent fashion. During the recession in 2009, total airline workforce as well as airlines' MRO employment dropped to the lowest points in many years.

Given the increased use of outsourcing, it seems likely that new jobs at maintenance companies unaffiliated with airlines have made up for at least some of the decline in airlines' employment of maintenance workers. Neither BTS nor the U.S. Bureau of Labor Statistics (BLS) compiles data on employment at third-party providers of maintenance for passenger airlines. BLS has a category called "Other Air Transportation Support Activities," which includes employment beyond passenger airline maintenance workers. The employee count in this group was more than 96,500 in 2011, having increased slightly since 2009.¹⁰

⁹ U.S. DOT, Federal Aviation Administration (FAA), "FAA Aerospace Forecast Fiscal Years 2012-2032," pp. 25-26.

¹⁰ It is unclear whether the BLS data include passenger aircraft MRO workers employed by third-party service providers and/or original equipment manufacturers (OEMs) such as Boeing and Airbus. The number of jobs generated as a result of foreign airlines sending aircraft to the United States for service is unknown. Separately, BLS publishes (continued...)

Major Factors Behind MRO Outsourcing

There are multiple factors behind airlines' use of foreign maintenance providers. The most commonly mentioned is cost savings from sending MRO work to lower-wage countries such as China and El Salvador.¹¹ While this is generally true, there are other factors influencing airlines' decision to perform MRO in other countries, including changes in route structures and the increasing availability of MRO services in emerging economies.

Cost Savings and Capital Investment

Although information regarding industry-specific MRO labor costs in various regions and countries appears to be very limited, a recent study in *Journal of Aviation Technology and Engineering* offers a brief comparison of labor costs in the United States and Central America:¹²

With foreign labor costs less than 50% of those in the U.S., it is easy to see that many air carriers have shifted their HMV (heavy maintenance visits) to overseas providers, with estimated savings at \$1 million per aircraft each year.... In 2008, starting pay at Aeroman [an MRO provider in El Salvador] was approximately \$4,500 per year with veterans earning approximately \$15,000. That compares to the U.S. average of \$52,000.... Narrow body HMV work tends to stay in the Western Hemisphere, with MRO providers in Central America playing a significant role; lower labor costs and shorter ferry flights contribute to cost savings.

Hiring out MRO enables airlines to avoid significant capital investment in facilities, equipment, and inventories of parts and components. For example, Aeroman has four hangars to accommodate 11 production lines for narrow-body aircraft. Its 564,000-square-foot facilities are housed in steel-framed concrete walls with fire protection systems.¹³ In addition, the heavy equipment, work stands, test tools, support equipment, and other items all demand a considerable outlay of capital.

The Chinese MRO sector seems to have benefited substantially from significant investment by the state, for example, newly built or upgraded airports with expansive hangars for maintenance and repair work.¹⁴ In 2010 alone, the Chinese government invested over Rmb 64.6 billion yuan

(...continued)

monthly data on both support activities for air transportation and a subset of that category, airport operations. These data series indicate an increase of approximately 20,000 jobs since 2000 in support activities for air transportation other than airport operations. The number of these jobs that involve aircraft maintenance is unknown.

¹¹ Transport Workers Union of America (TWU), *Aircraft Maintenance in America: Who is Fixing My Plane?*, March 2011.

¹² McFadden and Worrells, "Global Outsourcing of Aircraft Maintenance," *Journal of Aviation Technology and Engineering* 1:2 (2012) 63-73, DOI: 10.5703/1288284314659, pp. 64-65.

¹³ Aeroman specializes in maintenance of narrow-body aircraft, such as the Airbus A320 and Boeing 737. Aeroman company website, <http://www.aeroman.com.sv/en-company.jsp?idCat=6>, as viewed on November 1, 2012.

¹⁴ People's Republic of China (PRC) Ministry of Housing & Urban Development, PRC National Development & Reform Commission, "Civilian Airport Project Construction Standards, Construction Standards 105-2008," March 31, 2008, p. 11. CRS used the original Chinese-language version of this document.

(approximately \$9.5 billion) in its civil aviation system, including over Rmb 44 billion yuan (approximately \$6.5 billion) in airport construction and expansion.¹⁵

Global Network of Passenger Flights

In the past few decades, international air travel has grown considerably, with population growth, rising income, and the global expansion of business and travel. The aerospace industry has contributed to the fast expansion of global aviation networks by designing and manufacturing bigger and more efficient aircraft capable of flying longer distances. Meanwhile, the real cost of air travel has been reduced by more than 60% between 1970 and 2010, through deregulation of the aviation market and the emergence of low cost carriers.¹⁶ Nowadays it is more affordable for more of the world's population to travel by air. In 2010, the global passenger air travel network consisted of over 1,500 airlines, a total fleet of nearly 24,000 aircraft, and nearly 4,000 airports with scheduled commercial flights.

International air travel in and out of the United States more than doubled between 1990 and 2011.¹⁷ In 2011, U.S. airlines operated a total of 830,600 international flights, carrying 92.5 million travelers.¹⁸ The expansion of route networks around the globe made aircraft MRO in foreign countries simpler and less expensive by making it convenient for airlines to use foreign maintenance bases without incurring additional costs for ferrying aircraft. It also made foreign MRO necessary, at least with respect to emergency repairs, as international airlines need some ability to have maintenance work performed at all airports they serve.

Growing Aviation Market and the Presence of OEMs in Emerging Markets

Global aircraft MRO is estimated to be a \$50 billion market in 2012.¹⁹ Engine MRO remains the largest segment, accounting for over 45% of the total MRO value, followed by component MRO (over 19%), line maintenance (nearly 18%), and HMV (nearly 18%). Regionally, North America and Europe are the largest MRO markets, representing a combined share of over 57% of the total market. The Asia-Pacific region including China, which represented approximately 25% of the global MRO market in 2008, is the fastest-growing segment and projected to command 30% of the entire MRO market in 2013.²⁰

¹⁵ Civil Aviation Administration of China (CAAC), "The Growth of Civil Aviation Sector in 2010," May 5, 2011, http://www.caac.gov.cn/il/K3/201105/t20110504_39489.html. CRS used the original Chinese-language version of the document. The Renminbi (RMB or Rmb) is the official name of China's currency, and the yuan is the primary unit of the RMB. The exchange rate used for conversion is 6.8 yuan/U.S. dollar.

¹⁶ Air Transport Action Group (ATAG), "Aviation: Benefits Beyond Borders."

¹⁷ Brookings Institution, "Global Gateways: International Aviation in Metropolitan America," October 25, 2012.

¹⁸ BTS 14-12, "December 2011 Airline System Traffic Up 0.5 Percent from December 2010," Table 14.

¹⁹ TeamSAI Consulting Services estimated global MRO spending will be \$49.5 billion in 2012 in its "The Global MRO Forecast 2012-2022" at MRO Americas 2012 Conference; ICF SH&E projected global MRO spending to be \$50.9 billion in 2012 in its "MRO Market Overview" at *Aviation Week* Regional Conference in May 2012.

²⁰ Frost & Sullivan, "MRO Global Outlook," May 19, 2009; TeamSAI Consulting Services, "The Global MRO Forecast 2012-2022," at MRO Americas 2012 Conference.

In terms of global MRO service providers, approximately 42% of the MRO market share is taken by OEMs, including leading aircraft manufacturers (Boeing and Airbus) and primary aircraft engine OEMs (GE Aircraft Engines, Pratt & Whitney, and Rolls-Royce PLC). These three OEMs manufacture civil aircraft engines for most Boeing and Airbus aircraft as well as for Bombardier and Embraer regional jets. They also provide engine overhaul, repair, and fleet management services, as well as technical training. The leading OEMs have established a strong presence in fast-growing aviation markets such as China. Major airlines and their MRO subsidiaries, such as Air France/KLM and Lufthansa Technik, have 49% of the MRO market, and the remaining 9% is taken by third-party providers such as TIMCO and TAECO (see **Text Box**).

Global MRO Market Leaders in 2008

- Air France Industries / KLM Engineering & Maintenance
- Singapore Technologies Aerospace (ST Aerospace)
- Hong Kong Aircraft Engineering Company (HAECO)
- Lufthansa Technik
- TIMCO Aviation Services
- Aircraft Maintenance and Engineering Corp. (Ameco Beijing)
- SAI Engineering
- Taikoo (Xiamen) Aircraft Engineering Company (TAECO)
- British Airways Engineering
- AAR

Source: Frost & Sullivan, "MRO Global Outlook," May 19, 2009, p. 15.

MRO in China

Between 2000 and 2010, the commercial airline fleet in China more than doubled to over 1,300 airplanes and the number of passengers soared from 83 million to 202 million, at an average annual growth rate of over 10%.²¹ Between 2010 and 2028, Chinese airlines are expected to purchase 3,770 new airplanes, with a market value of \$400 billion, according to Boeing's *Commercial Market Outlook 2012*.²²

The MRO sector in China has grown along with the airline industry. The Civil Aviation Administration of China (CAAC), which oversees the country's aviation system, has encouraged the growth of the MRO sector with government investment and other state incentives.

In June 2011, CAAC issued a document to guide the development of China's MRO sector through 2016. According to this document, there were 389 aircraft MRO companies in China at

²¹ Boeing company website, "Feature Story: The Great Call of China," http://www.boeing.com/Features/2010/05/bca_shanghai_expo_05_03_10.html, as viewed on October 26, 2012; Civil Aviation Administration of China (CAAC), Flight Standards Division, "Guidelines of the Civil Aviation MRO Industry Development in the 12th Five-year Plan," June 2011, <http://www.china-cam.cn/Files/0002010/11070801.pdf>. CRS used the original Chinese-language version of the document.

²² Boeing Company website, as viewed on November 1, 2012, <http://www.boeing.com/commercial/cmo/>.

the end of 2010, more than 30 of which were certified by the U.S. Federal Aviation Administration (FAA), the European Aviation Safety Agency (EASA), or both. As of the same date, 331 foreign repair providers had received certification from China, which enables them to work on airplanes operated by Chinese air carriers. There were a total of 104 hangars in China, able to accommodate more than 360 wide- and narrow-body aircraft for maintenance and repair.²³

In 2010 the Chinese MRO sector had about \$2.3 billion in revenue, nearly 5% of the global total. However, Chinese companies had less than 25% of their own domestic market, based on annual revenues, because many of these Chinese companies lack technological or engineering sophistication needed to handle high-value and more sophisticated MRO projects, such as engine work. Chinese air carriers, the document noted, have to send about 70% of their engine overhaul to foreign-owned companies every year.²⁴

The CAAC document also indicates that MRO professionals are in short supply in China's civil aviation sector, which would need at least 24,000 more technicians by 2015. Furthermore, there appears to be a significant knowledge and experience gap in existing MRO employees, many of whom are relatively young with inadequate work experience. In addition, there is a serious shortage in inspectors overseeing their work and ensuring work quality. With 212 inspectors overseeing some 42,000 MRO technicians, the ratio is approximately 1 inspector for every 200 maintenance technicians. By the end of 2010, there were 44 MRO training schools certified by the government.²⁵

Major foreign OEM and MRO companies doing business in China, such as Boeing and Airbus, provide training to aircrew, cabin crew, and maintenance technicians, some from outside China. For example, Boeing Shanghai Aviation Services Co. Ltd. (Boeing Shanghai), a joint venture with China Eastern Airlines and the Shanghai Airport Authority, is an MRO center performing line maintenance, heavy maintenance, and airframe modifications, as well as upgrades of airplane interiors, avionics, and in-flight entertainment systems. In cooperation with Chinese airlines, CAAC, and industry, Boeing has provided professional training to nearly 40,000 Chinese aviation professionals since 1993. The training provided by foreign OEMs has helped to improve the skill levels of Chinese aviation professional and maintenance workers, some of whom service U.S. aircraft. In June 2012, Boeing announced plans to expand training capacity at its Boeing Shanghai Aviation Services campus to include the addition of a program to train workers to maintain its new 787 Dreamliner.²⁶

Another leading MRO company in China, Aircraft Maintenance & Engineering Co. (AMECO Beijing), was established in 1989 as a joint venture between Air China Ltd. and Lufthansa Airlines. AMECO Beijing provides MRO services for airframe, engines, and components, as well as services in training, engineering, and logistics.²⁷

²³ Civil Aviation Administration of China (CAAC), Flight Standards Division, "Guidelines of the Civil Aviation MRO Industry Development in the 12th Five-year Plan," June 2011, <http://www.china-cam.cn/Files/0002010/11070801.pdf>. CRS used the original Chinese-language version of the document.

²⁴ Ibid.

²⁵ Ibid.

²⁶ Boeing company website, "Boeing in China," as viewed on November 7, 2012, <http://www.boeing.com/aboutus/international/docs/backgrounders/chinabackgrounder.pdf>.

²⁷ Ameco Beijing website, as viewed on September 10, 2012, <http://www.ameco.com.cn/english/company/index.htm>.

Another major China-based global MRO provider is Taikoo Aircraft Engineering Company (also known as TAECO). The company is based at Gaoqi International Airport in the Chinese city of Xiamen, with a 58.55% stake controlled by Hong Kong Aircraft Engineering Co. (also known as HAECO). TAECO's customers include American Airlines, Delta Airlines, FedEx, Air Canada, Korean Air, and Deutsche Lufthansa AG, British Airways, and Air France/KLM.²⁸

Work performed at a TAECO facility raised safety concerns in November 2011 after about 30 screws were found missing from a large protective panel on an Air France Airbus A340 wide-body jet after it had undergone routine maintenance in China.²⁹ An Air France union spokesperson, reportedly, indicated that there had been another incident in 2010 when "a Boeing 747 was grounded after undergoing maintenance in China because parts of the plane had been painted with flammable paint."³⁰ On December 1, 2011, Air France announced that an investigation was under way and that it had stopped sending aircraft to TAECO, which had been providing maintenance service to 10% Air France's long-haul fleet.³¹

MRO in El Salvador

Although El Salvador is a comparatively small country, it plays a significant role in the maintenance, repair, and overhaul of U.S. airliners. Its relative proximity to major airline hubs in the United States has contributed to its growth as a major repair center for narrow-body jets. There are three FAA-certified repair stations in El Salvador. The TACA International Airlines repair facility at its San Salvador hub employs almost 500 personnel, including 61 FAA-certified mechanics as well as 116 mechanics not certified by the FAA. AvioTechnology is a small facility with five employees, including two FAA certified mechanics, that specializes in installing remanufactured aircraft brakes and wheels. Aeroman is major repair and overhaul facility that employs more than 1,800, including 143 FAA-certified mechanics and 1,125 mechanics that are not FAA certified. Aeroman, 80% owned by the bankrupt Canadian company Aveos Fleet Performance Inc., provides a broad array of MRO services for U.S. air carriers, including Southwest Airlines, JetBlue, and US Airways. It has been certified as a repair facility by FAA since 1992.³²

Aeroman has been the subject of press attention because of its rapid growth as a provider of contract maintenance service to U.S. airlines. In October 2009, National Public Radio (NPR) examined Aeroman as part of a series on airline maintenance offshoring practices, and in May 2011, KIRO TV in Seattle, WA, reported on alleged deficiencies and errors at Aeroman.³³ Both

²⁸ Ibid.; TAECO company website, <http://www.taeco.com>, as viewed on October 16, 2012. Other shareholders of TAECO include Boeing Co., Cathay Pacific Airways Ltd., Japan Airlines Co., Xiamen Aviation Industry Co., and Beijing Kailian Aviation Technology Development and Service Co.

²⁹ "Air France A340 flew with missing screws after shop visit," *BusinessWeek*, November 25, 2011.

³⁰ "Air France plane grounded after technicians noticed 30 screws were missing from wing... after FIVE days of flights," *Daily Mail*, November 25, 2011.

³¹ "Air France suspends maintenance in China," Agence France-Presse (AFP), December 1, 2011.

³² Although Aveos initiated a liquidation of its Canadian facilities and assets in March 2012, it has been reported that Aeroman was unaffected because it had been maintained as a separate corporate entity; see François Shalom, "Aveo's Ownership Is a Mystery; Former Buyers Left Empty-Handed; Company Is Privately Held in the Murky Tax Havens of Cayman Islands, Luxembourg," *Gazette* (Montreal, Canada), March 23, 2012.

³³ Daniel Zwerdling, "To Cut Costs, Airlines Send Repairs Abroad," *National Public Radio*, October 19, 2009; "Crossed Wires: Flaws in Airline Repairs Abroad," *National Public Radio, Morning Edition*, October 20, 2009; "Third-World Mechanics Paid \$2 Per Hour for Boeing, Airbus Jet Repairs," *KIRO TV, Seattle, Washington*, May 16, (continued...)

investigations highlighted incidents involving improper installation of door components and seals and improper wiring. A door seal component installation error traced back to Aeroman was discovered on a US Airways aircraft in flight in January 2009 and resulted in FAA-issued violations against both US Airways and Aeroman for lapses in maintenance and oversight. The wiring errors involved two aircraft whose engine monitoring gauges were cross-wired, so the reading from the right engine showed on the gauge for the left engine and vice versa. Such an error could cause a pilot to shut down the wrong engine if engine trouble was suspected.³⁴ No additional incidents involving Aeroman maintenance have been reported in the media.

Aeroman employees interviewed by KIRO TV in 2011 stated that newly hired mechanics at Aeroman make about \$2 per hour, while mechanics with a decade of experience earn about \$5 per hour, which is regarded as a high-paying job in San Salvador. Employees estimated that roughly 40% of maintenance workers at Aeroman are fluent enough in English to read and comprehend aircraft maintenance manuals. Workers complained about time pressures, poor training, and inexperience, although one expert pointed out that similar complaints are commonplace in the industry and not unique to Aeroman.³⁵ Similarly, Aeroman employees interviewed by NPR in 2009 had expressed concern over time pressures, use of improper parts, improper storage of materials such as glues, and lack of English proficiency among workers.³⁶ Aeroman CEO Ernesto Ruiz countered that his company has provided its customers with high-quality, on-time service, and that airlines would not contract with facilities “where quality is not a guarantee.”³⁷

Safety and Reliability Issues

Foreign repair stations have been the subject of safety concerns at least since 1995, when the crash of a U.S. passenger plane was attributed to faulty repair work undertaken abroad (see **Text Box**). The issues raised have included quality control procedures; the level of regulatory oversight; mechanic pay, skill, training, and experience; the degree of qualified supervision; the lack of English language skills or requirements to read and comprehend maintenance manuals; and the absence of drug and alcohol testing programs on par with those required at U.S. repair stations.

(...continued)

2011, <http://www.kirotv.com/news/news/third-world-mechanics-paid-2-per-hour-for-boeing-a/nDNwr/>.

³⁴ “Crossed Wires: Flaws in Airline Repairs Abroad,” *National Public Radio, Morning Edition*, October 20, 2009.

³⁵ “Third-World Mechanics Paid \$2 Per Hour for Boeing, Airbus Jet Repairs,” *KIRO TV, Seattle, Washington*, May 16, 2011, <http://www.kirotv.com/news/news/third-world-mechanics-paid-2-per-hour-for-boeing-a/nDNwr/>.

³⁶ “Crossed Wires: Flaws in Airline Repairs Abroad,” *National Public Radio, Morning Edition*, October 20, 2009.

³⁷ “Third-World Mechanics Paid \$2 Per Hour for Boeing, Airbus Jet Repairs,” *KIRO TV, Seattle, Washington*, May 16, 2011, <http://www.kirotv.com/news/news/third-world-mechanics-paid-2-per-hour-for-boeing-a/nDNwr/>.

1995 Accident Linked To Foreign Repair Station Error

A June 1995 accident involving a ValuJet DC-9 taking off from Atlanta, GA, was directly attributed to errors made at a foreign repair station. The aircraft experienced an uncontained engine failure and subsequent fire that seriously injured a flight attendant and caused minor injuries to another flight attendant and five passengers. The National Transportation Safety Board (NTSB) determined that the probable cause of the accident was improper inspection of the engine during a 1991 overhaul at a maintenance facility in Turkey. Inadequate recordkeeping and a lack of systematic procedures at the facility contributed to the failure to detect a crack that grew over time and led to the engine failure, according to NTSB.³⁸

Following the accident, NTSB recommended that FAA require all foreign repair stations to adhere to the same recordkeeping requirements as domestic repair stations and that FAA provide guidance regarding the detailed documentation of inspections and overhauls. FAA modified its regulations to strengthen recordkeeping requirements for foreign repair stations in December 2001. Since then, no further accidents have been linked to work performed at foreign repair stations. However, as this accident illustrates, maintenance errors may lead to latent accident preconditions that may take months or years to reveal themselves.

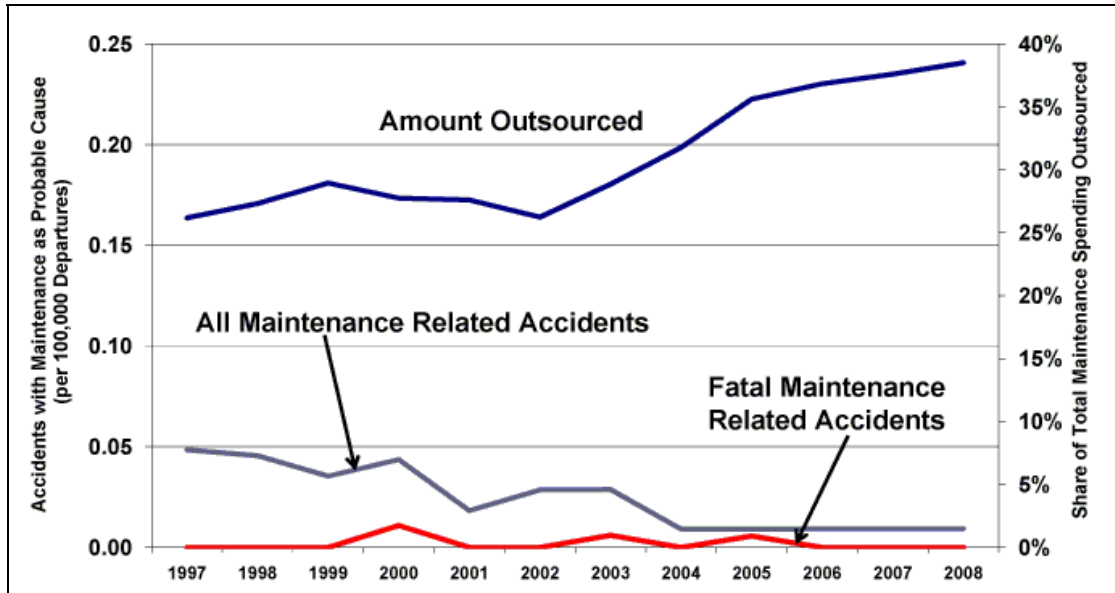
Airlines have an interest in making sure that outsourced maintenance is of the highest quality to avoid costly delays and cancellations. Moreover, airlines and aircraft repair service providers assert that the high economic value placed on safety in the airline industry is by itself sufficient incentive to promote high-quality performance among foreign repair stations that maintain U.S. air carrier aircraft. Airlines for America, the advocacy organization for major U.S. air carriers, cited NTSB data showing that, as U.S. airlines have increased their maintenance outsourcing to global providers, “maintenance as a probable cause [of accidents] declined from 0.05 per 100,000 departures to absolute zero in recent years. The industry’s safety record remains unmatched; no evidence indicates that offshore MRO services are unsafe or insecure.”³⁹ The group has released data showing that maintenance-related accidents have declined since 1997 despite increased outsourcing of maintenance (see **Figure 5**). This position is supported by a comprehensive research study that failed to find any relationship between airline maintenance outsourcing rates and aircraft accident and incident rates from 1996 to 2008, although the study did not specifically differentiate between domestic outsourcing and offshoring.⁴⁰

³⁸ National Transportation Safety Board, *Aircraft Accident Report: Uncontained Engine Failure/Fire, ValuJet Airlines Flight 597, Douglas DC-9-32, Atlanta, Georgia, June 8, 1995*, NTSB/AAR-96-03, Washington, DC, August 30, 1996.

³⁹ Airlines for America, “ATA Testimony by CEO Jim May before the Senate Aviation Subcommittee on FAA Reauthorization,” May 13, 2009, <http://airlines.org/Pages/ATA-Testimony-by-CEO-Jim-May-before-the-Senate-Aviation-Subcommittee-on-FAA-Reauthorization.aspx>

⁴⁰ Kari M. Monaghan, “Examining the Relationship Between Passenger Airline Aircraft Maintenance Outsourcing and Aircraft Safety,” (Ph.D. Dissertation, Northcentral University, Prescott Valley, AZ, 2011).

Figure 5. Outsourcing Trends and Maintenance-Related Accidents Among Major U.S. Air Carriers, 1997-2008



Source: Airlines for America, “ATA Testimony by Vice President Basil Barimo before the House Transportation Security and Infrastructure Protection Subcommittee on Repair Station Security,” November 18, 2009, <http://www.airlines.org/Pages/ATA-Testimony-by-Vice-President-Basil-Barimo-before-the-House-Transportation-Security-and-Infrastructure-Protection-Sub.aspx>.

However, some safety experts caution that the absence of a link between outsourced maintenance and safety is not conclusive evidence that offshoring maintenance work does not have safety implications. Experts point out that FAA does not track in detail where airline aircraft are maintained and exercises limited oversight of foreign repair stations. Former NTSB board member John Goglia, a long-time critic of cost cutting in airline maintenance, recently expressed particular concern that much critical maintenance work continues to be performed with little FAA review, particularly unannounced inspector review, and this is especially the case at foreign repair facilities.⁴¹

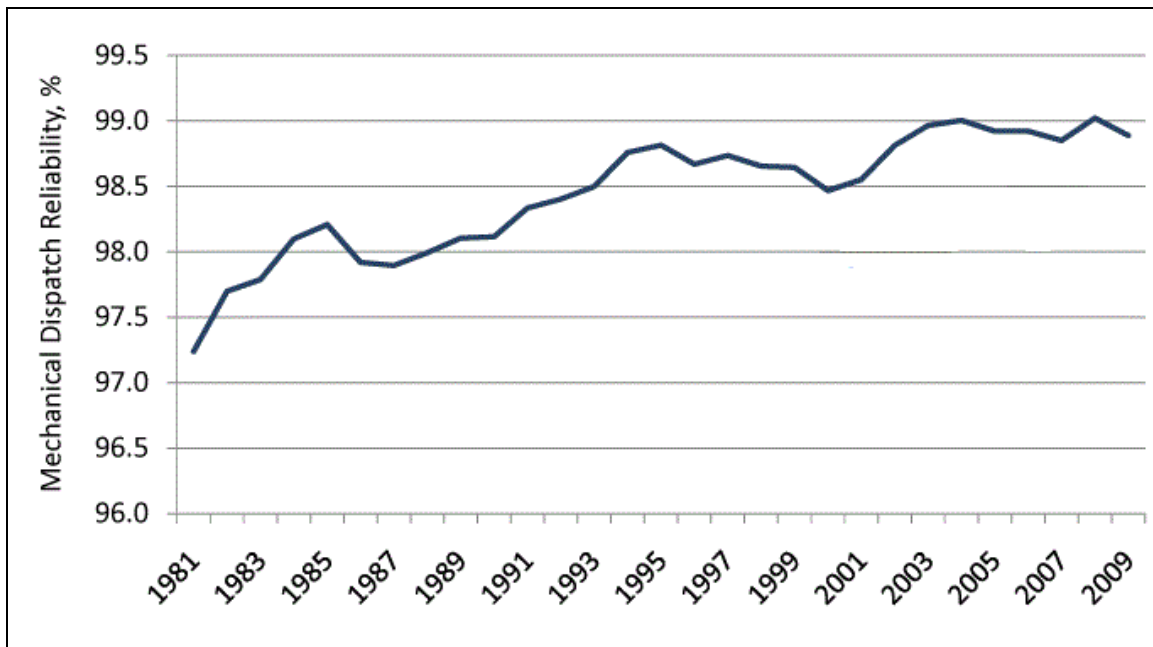
Statistical analysis of the relationship between airline service reliability and maintenance outsourcing also is inconclusive. In 2007, *Consumer Reports* magazine reported a steady increase in both outsourced maintenance and the number of airline flight cancellations from 2002 through 2004, but did not specifically differentiate between domestic outsourcing and offshoring.⁴² The report also provided data pointing toward a correlation between outsourced maintenance and airline-caused delays among 14 major U.S. air carriers in 2005. Based on these data alone, it is not possible to assess whether maintenance outsourcing was a direct cause of cancellations and delays, as airlines may have implemented other cost-cutting measures, such as reducing ground crews, which also may have contributed to delays.

⁴¹ John Goglia, “AIN Blog: Torqued: Robust Regulatory Oversight Remains Backbone of Aviation Safety,” AIN Online, December 1, 2012, <http://www.ainonline.com/aviation-news/blogs/ain-blog-torqued-robust-regulatory-oversight-remains-backbone-aviation-safety>.

⁴² “An Accident Waiting To Happen?: Outsourcing Raises Air-Safety Concerns,” *Consumer Reports*, March 2007, pp. 16-19.

In contrast, Airlines for America points to Boeing data showing that U.S. airlines' operations utilizing Boeing commercial jets have improved their mechanical dispatch reliability, an indicator of the effectiveness of airline maintenance programs, from about 98.1% in 1991, to between 98.9% and 99.0% in 2008 and 2009 (see **Figure 6**).⁴³ While the data show relatively consistent improvement in airline maintenance reliability over the past three decades, the exact relationship between outsourcing practices and maintenance dispatch reliability over time is unclear because of cyclical fluctuations in the data that are most likely attributable to the aging of the fleet and the somewhat periodic or cyclical nature of airline fleet replacement programs. Moreover, improved reliability of newer aircraft may be the primary factor influencing dispatch reliability and may mask any trends related to outsourcing practices.

Figure 6. Mechanical Dispatch Reliability
Boeing Commercial Aircraft Operated by U.S. Air Carriers



Source: Airlines for America, "ATA Testimony by Vice President Basil Barimo before the House Transportation Security and Infrastructure Protection Subcommittee on Repair Station Security," November 18, 2009, <http://www.airlines.org/Pages/ATA-Testimony-by-Vice-President-Basil-Barimo-before-the-House-Transportation-Security-and-Infrastructure-Protection-Sub.aspx>.

Notes: Mechanical dispatch reliability is inversely related to the number of cancellations and departure delays for mechanical reasons.

⁴³ Airlines for America, "ATA Testimony by Vice President Basil Barimo before the House Transportation Security and Infrastructure Protection Subcommittee on Repair Station Security," November 18, 2009, <http://www.airlines.org/Pages/ATA-Testimony-by-Vice-President-Basil-Barimo-before-the-House-Transportation-Security-and-Infrastructure-Protection-Sub.aspx>.

Regulatory Oversight

Maintenance of U.S. air carrier aircraft at both foreign and domestic locations is subject to regulation and oversight by FAA. Repair stations are regulated under Title 14 Code of Federal Regulations, Part 145, and thus, FAA-certificated repair stations are sometimes referred to as Part 145 repair stations. To be certified under Part 145, a repair station must develop FAA-approved documentation and processes, including quality control procedures and training programs. FAA may also approve foreign repair stations based on a foreign certification issued by a country that has a bilateral aviation safety agreement with the United States.

From a regulatory standpoint, FAA reviews and recertifies foreign repair stations annually, or in some cases every two years, whereas domestic repair stations can retain their certification indefinitely unless FAA is prompted to suspend or revoke it based on specific safety concerns. While FAA establishes requirements for foreign repair stations, much of the direct oversight to ensure compliance is conducted by foreign regulatory entities under bilateral agreements and a multilateral agreement with the European Union. A summary of key differences in FAA regulatory requirements for domestic and foreign repair stations is presented in **Table 1**.

Table 1. Regulatory Differences Between Domestic and Foreign Repair Stations

Regulatory Requirement	Domestic	Foreign
Certification	Indefinite unless suspended or revoked	Renewed annually, or in some cases, every two years if FAA determines that the facility has operated in compliance with regulations over the preceding year.
Certification, Renewal, and Inspection Fees	No fees	Fees (2012 rate is \$157 per inspector per hour)
Certificated Mechanics	Certain personnel, including supervisory personnel and individuals authorized to approve an aircraft's return to service, must be FAA-certificated mechanics	No FAA certification requirement for personnel. However, supervisors must meet minimum experience requirements and the repair station must have an FAA-approved training program. Foreign countries may have separate certification requirements for mechanics.
Drug and Alcohol Testing Programs	Required	Under development as required by P.L. 112-95
Security Regulations	Repair stations on commercial airport property are subject to TSA regulation. Security regulation of repair facilities at non-commercial airports and off-airport facilities is being developed by TSA as required by P.L. 108-176.	Security regulation being developed. Foreign repair stations are subject to security reviews and audits under P.L. 108-176. No new foreign repair stations can be certified by FAA until the required regulations are finalized. This does not affect renewals of existing repair station certificates

Source: Department of Transportation, Office of Inspector General, *Aviation Safety: FAA Oversight of Foreign Repair Stations*, Statement of the Honorable Calvin L. Scovel III, Inspector General, Before the Committee on Commerce, Science, and Transportation, Subcommittee on Aviation Operations, Safety, and Security, United States Senate, June 20, 2007; CRS analysis of the Code of Federal Regulations, U.S. Code, and existing law.

Thus, regulatory requirements for foreign repair station certification are somewhat more stringent than those for domestic repair stations, although foreign repair stations do not have the same requirements as U.S. repair stations with respect to certification of supervisors and individuals authorized to sign off on work performed and return aircraft to service.

Moreover, there are concerns that FAA's resources and capabilities to inspect foreign repair stations are spread thin. FAA has 10 international field offices and units, although only 2 (Frankfurt and Singapore) are physically located outside the United States. Collectively, these 10 offices house about 100 inspectors who have primary oversight responsibility for almost 700 foreign repair stations in addition to overseeing foreign air carriers that operate flights to the United States. In total, FAA employs about 4,100 inspectors, so the number of inspectors dedicated full time to oversight of foreign entities, including foreign repair stations, constitutes only a small percentage of the total FAA inspector workforce.

FAA inspectors who oversee air carrier maintenance are also responsible for ensuring that work contracted to third parties, including foreign repair stations, adheres to applicable regulations and FAA-approved air carrier procedures. In 2008, the DOT OIG found that FAA's system for determining where to target inspections was inadequate, relying too heavily on incomplete voluntary air carrier reporting of maintenance outsourcing and air carrier audits that varied considerably in their quality and completeness.⁴⁴ In particular, the DOT OIG found that FAA was over-reliant on air carriers' initial audits of repair stations to approve substantial maintenance providers for use by air carriers. The DOT OIG found that, in some cases, more than five years passed from the time a facility was first approved for air carrier use until inspectors responsible for overseeing a specific carrier's maintenance programs conducted an inspection.

With regard to maintenance work sent to foreign repair stations, the DOT OIG also raised concerns regarding logistical challenges and procedural and cultural barriers that may limit the effectiveness of FAA inspector oversight activities in foreign countries. The DOT OIG noted that the time-consuming process of obtaining visas and other clearances to travel to foreign facilities often gives these facilities several months' advance notice of an upcoming inspection, thus giving foreign repair stations considerable forewarning and thus making it impossible to conduct surprise inspections.⁴⁵

The DOT OIG specifically highlighted concerns over the imbalance in FAA inspector staffing, particularly in light of the increasing trend among airlines to outsource maintenance, often to overseas facilities.⁴⁶ In 2007, the DOT OIG concluded that FAA still needed to develop an effective process for placing its inspector workforce where it is most critically needed,⁴⁷ despite language in the 2003 FAA reauthorization act directing FAA to revamp its inspector staffing model.

⁴⁴ U.S. Department of Transportation and Office of Inspector General, *Review of Air Carrier's Outsourcing of Aircraft Maintenance*, Report Number AV-2008-090, September 30, 2008.

⁴⁵ Ibid.

⁴⁶ U.S. Department of Transportation and Office of Inspector General, *Review of Air Carriers' Use of Aircraft Repair Stations*, Report No. AV-2003-047, 8, 2003.

⁴⁷ U.S. Department of Transportation and Office of Inspector General, *Aviation Safety: FAA Oversight of Foreign Repair Stations*, Statement of the Honorable Calvin L. Scovel III, Inspector General, U.S. Department of Transportation, Before the Committee on Commerce Science, and Transportation, Subcommittee on Aviation Operations, Safety, and Security, United States Senate, Washington, DC, June 20, 2007, CC-2007-076.

In April 2012, the DOT OIG reported that, while FAA had implemented a new risk-based system for targeting its repair station surveillance activities following the DOT OIG's 2007 report, the system is being applied inconsistently by FAA inspectors, and surveillance at foreign repair facilities lacked the rigor needed to identify deficiencies and subsequently verify that corrective actions had been taken. The DOT OIG also found that systematic problems it previously identified still persist, including inadequacies in mechanic training, outdated tool calibration checks, and inaccurate work documentation.⁴⁸ These concerns are not unique to foreign repair stations, as they were observed at domestic repair stations as well.

The Role of Foreign Regulatory Agencies

Foreign regulatory agencies serve a crucial role in the oversight of maintenance performed on U.S. air carrier aircraft overseas. Under reciprocal bilateral aviation safety agreements, FAA delegates some routine inspection functions to the foreign regulator, and FAA is granted negotiated rights to review the foreign regulator's audit and inspection findings. The United States currently has in place about 28 bilateral aviation safety agreements, mostly with European countries. In addition, the United States has entered into a comprehensive multilateral agreement with the European Union (EU) that took effect in May 2011 and includes a detailed annex that provides a structure for coordination of maintenance oversight between the United States and EU member countries. Similarly, the United States and Canada have had formal procedures governing the coordination of repair station oversight in place since 2000.

Other countries, including El Salvador and China, however, do not have formal aviation safety agreements in place with the United States. While these countries provide their own regulatory structure for repair stations, these measures are not formally recognized by the United States and FAA primarily relies on its own oversight to monitor safety compliance among these facilities.

In 2007, the DOT OIG had found that in some cases where foreign authorities conducted inspections under reciprocal agreements with FAA, FAA was often not provided with sufficient information to determine what inspections covered, what deficiencies were found, and what corrective actions were recommended or made.⁴⁹ In many cases, the DOT OIG concluded that inspection documentation was incomplete or incomprehensible, and that foreign inspectors in Europe often focused only on European regulations and not on FAA requirements, missing deficiencies such as FAA-specific tool calibration requirements and prohibitions on subcontracting to facilities that were not FAA-certified. In some cases, inspection documents were not provided in English and FAA had not assigned inspectors fluent in the foreign language used, in these cases French, to review the documents. The DOT OIG concluded that FAA could not adequately verify that inspections conducted by foreign authorities on its behalf ensured that these facilities met FAA standards. It has not reported on whether these problems have been adequately addressed over the past decade or how relations under the recent aviation safety agreement between the EU and the United States have served to address these concerns.

⁴⁸ Department of Transportation, Office of Inspector General, *The State of Aviation Safety and FAA's Oversight of the National Airspace System*, Statement of Jeffrey B. Guzzetti, Assistant Inspector General for Aviation and Special Programs, CC-2012-018, April 25, 2012, pp. 6-7.

⁴⁹ U.S. Department of Transportation and Office of Inspector General, *Aviation Safety: FAA Oversight of Foreign Repair Stations*, Statement of the Honorable Calvin L. Scovel III, Inspector General, U.S. Department of Transportation, Before the Committee on Commerce Science, and Transportation, Subcommittee on Aviation Operations, Safety, and Security, United States Senate, Washington, DC, June 20, 2007, CC-2007-076.

Provisions in the 2012 FAA reauthorization act (P.L. 112-95) address concerns over bilateral aviation safety agreements with respect to FAA inspection authority. Specifically, the act requires FAA to ensure that foreign repair stations are subject to appropriate inspections consistent with existing U.S. requirements and that agreements with foreign aviation authorities or other foreign government agencies provide an opportunity for FAA to conduct independent inspections of foreign repair stations when warranted by safety concerns. Additionally, the act requires FAA to conduct annual inspections at all foreign repair stations consistent with obligations under international agreements.

The Role of the Airline Industry

Airlines normally conduct rigorous reviews and inspections of contract repair shops as a condition of awarding contracts and on a continuing basis to ensure safety standards stipulated in these contracts are maintained. Airline oversight of contract repair facilities includes detailed preliminary investigations and on-site visits prior to contract awards, periodic on-site inspections and audits, and continuous monitoring of ongoing repair work by on-site air carrier representatives.

FAA relies on air carriers to provide oversight of contracted repair stations as part of their overall safety programs. However, in 2008 the DOT OIG found that two of nine major air carriers did not document their spot inspections of repairs and had no method for ensuring corrective actions were taken or tracking trends in repair station errors.⁵⁰ Presence of air carrier on-site personnel on the hangar floor observing contract repair operations ranged from 35% to 70% of the time. The number of personnel also varied considerably, ranging from 3 on-site monitors from one carrier to 22 from another at repair stations examined in the DOT OIG audit. DOT OIG recommended that FAA establish formal procedures for air carrier personnel to document their observations and share them with FAA inspectors.

The Role of Airframe and Engine Manufacturers

Airframe, engine, and aircraft component manufacturers have a regulatory responsibility to disseminate information regarding the maintenance of their products to assure that they can continue to be operated in an airworthy manner. Recently, manufacturers have taken a more direct role in MRO by establishing global MRO networks.

For example, Airbus has established a worldwide MRO network that includes 18 repair stations in Europe, the Middle East, and Central and South America. The network currently includes many foreign repair stations that contract to U.S. air carriers including Aeroman in El Salvador, as well as Hong Kong Aircraft Engineering Company (HAECO), TIMCO Aviation Services in the United States, Lufthansa Technik AG, and Mexicana MRO Services. Boeing is a joint venture partner in Boeing Shanghai Aviation Services, mentioned above, and is currently developing a similar joint venture with Air India in Nagpur, India, that is scheduled to open in 2013; it is unclear whether this facility will service U.S. air carrier aircraft. Similarly, Boeing is working with both U.S. carriers and foreign airlines to adopt its “GoldCare” and “Boeing Edge” lifecycle management and maintenance programs using Boeing-selected MROs.

⁵⁰ U.S. Department of Transportation and Office of Inspector General, *Review of Air Carrier's Outsourcing of Aircraft Maintenance*, Report Number AV-2008-090, Washington, DC, September 30, 2008.

Similar trends are taking place among engine manufacturers. For example, Lufthansa Technik and GE Aviation announced a long-term material service agreement in October 2012.⁵¹ GE already maintains an extensive MRO network overseas, with an extensive presence in Asia and Europe. Similarly, in 2010, Pratt & Whitney and Turkish Technic launched Turkish Engine Center (TEC) in Istanbul as a joint venture for engine MRO.

The larger role played by airframe and engine manufacturers in MRO around the world may eventually lead to the emergence of large specialty centers for MRO and greater standardization of global services. This could have broad implications for U.S. air carrier maintenance, including the potential for increased offshoring if maintenance practices and quality of service become increasingly standardized throughout the world. Some independent MROs are expressing concern that manufacturers' forays into maintenance operations are making it increasingly difficult for MROs that are not partnering with the manufacturers to access technical data and parts for aircraft that they service.

These ongoing changes in the MRO industry on a global scale will likely have important implications for the role of regulators. For example, FAA now focuses on airlines' maintenance activities in conjunction with its oversight of their air carrier certificates. If airlines continue to outsource both maintenance and now the management of that maintenance, the focus of FAA's oversight on airline practices may not be the most appropriate model moving forward.

Workforce Issues

Considerable concern has been raised in the media regarding pay rates for foreign repair station workers, particularly those located in Latin America. For example, it has been reported that at Aeroman in El Salvador new workers start at about \$4,500 annually and experienced mechanics make about \$15,000 per year.⁵² However, another source indicates that hourly rates charged for skilled mechanics across Central America are considerably higher, averaging \$36 per hour, but still considerably below comparable wages in the United States of \$53 per hour.⁵³ Moreover, comparing these figures to U.S. salaries is misleading without additional consideration of the relative purchasing power of these wages. In 2010, per capita gross domestic product in El Salvador, adjusted for purchasing power parity (PPP), was around \$7,500, compared to \$47,800 in the United States.⁵⁴

In other foreign hubs for MRO activity, wages for aircraft maintenance workers are higher, but do not appear to fully compensate for higher living costs. For example, in Singapore, the median annual wage for aircraft engine mechanics was roughly \$31,600 in 2010.⁵⁵ However, PPP adjusted per capita GDP in Singapore was \$57,900, considerably higher than the United States.⁵⁶

⁵¹ Lee Ann Tegtmeier, "Lufthansa, GE Sign Cooperative MRO Agreement," *Aviation Week Intelligence Network (AWIN)*, October 12, 2012.

⁵² Geri Smith and Justin Bachman, "U.S. Airlines Outsource Majority of Repairs," *Bloomberg Businessweek*, April 18, 2008.

⁵³ Lee Ann Tegtmeier, "Central America: An Emerging Market; MROs Develop Narrowbody Niches to Support Central and North American Fleets," *Overhaul & Maintenance*, April 2011.

⁵⁴ Central Intelligence Agency, *World Factbook*, <https://www.cia.gov/library/publications/the-world-factbook/index.html>.

⁵⁵ CRS analysis based on data provided in Singapore Government, Ministry of Manpower, *Report on Wages in Singapore 2010: Statistical Tables*, [http://www.mom.gov.sg/statistics-publications/national-labour-market-information/\(continued...\)](http://www.mom.gov.sg/statistics-publications/national-labour-market-information/(continued...))

While wage imbalances pose significant challenges for U.S. workers competing in a global marketplace for skilled work as airline mechanics, jobs at foreign repair stations would appear to be sufficiently high paying on a comparative basis to attract considerable competition in local and regional job markets, particularly in Latin American countries. This may not, however, always hold true in high-growth Asian countries, such as Singapore, where advanced technical skills are in high demand in other fields that may compete for top talent and offer higher wages.

From a safety standpoint, the skill and experience of maintenance and repair workers at foreign MROs is a greater concern. In at least some countries, significant growth in MRO employment has been supported by the availability of technical training to develop a skilled labor force. For example, in El Salvador, the Universidad Don Bosco began offering a certificate program in aviation maintenance approved by El Salvador's Civil Aviation Authority in 2005. However, Aeroman workers told investigative reporters that much of the hard labor is done by young workers with minimal education and that some jobs go to unqualified members of politically connected families.⁵⁷ The workers also commented that they personally could do a better job if the company allowed them to get certified.

Some aspects of aircraft maintenance, notably engine maintenance, require comparatively advanced technical and engineering skills. These appear to be in shorter supply in some other countries than in the United States. While airlines in many countries appear to be offshoring routine maintenance and overhaul to foreign countries where labor is comparatively cheap, the United States appears to enjoy an advantage in advanced maintenance capabilities in the globalized MRO marketplace. This advantage could erode in the future if offshore maintenance centers in Asia and Central America begin to invest more heavily in advanced technical training.

Work Supervision

Although mechanics that are not certificated by the FAA can work on U.S. civil aircraft, only FAA-certificated mechanics can oversee, approve, and certify the work before an aircraft can be returned to service. FAA-certificated mechanics thus represent a form of front-line supervision, particularly at large full-service foreign repair stations, where fewer mechanics have FAA certification. Many smaller foreign repair stations have no certificated mechanics, as this is not a requisite for obtaining an FAA repair station certificate. These smaller facilities often work on aircraft components, and their work can be certified by airline mechanics or mechanics at larger facilities for which they perform subcontracted work.

Labor unions in the United States have raised significant concerns regarding the ratio of FAA-certificated mechanics to non-certificated mechanics at foreign repair facilities. A 2011 report by the Transportation Workers Union of America, which represents American Airlines mechanics, asserted that, at larger foreign repair stations, “the ratio of FAA licensed to unlicensed mechanics

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publications/Pages/wages-2010-table.aspx.

⁵⁶ Central Intelligence Agency, *World Factbook*, <https://www.cia.gov/library/publications/the-world-factbook/index.html>.

⁵⁷ “Third-World Mechanics Paid \$2 Per Hour for Boeing, Airbus Jet Repairs,” *KIRO TV, Seattle, Washington*, May 16, 2011, <http://www.kirotv.com/news/news/third-world-mechanics-paid-2-per-hour-for-boeing-a/nDNwr/>.

is mind boggling.”⁵⁸ Table 2 provides data on the numbers FAA-certificated and non-certificated mechanics at selected FAA-certificated Part 145 repair stations.

Table 2. FAA Certification of Repair Station Mechanics

Repair Station	Country	Total Employees	Non-Certificated Mechanics and Repairmen	Certificated Mechanics	Ratio ^a
Aeroman	El Salvador	1,842	1,125	143	7.9:1
TACA	El Salvador	476	116	61	1.9:1
AMECO	China	6,234	3,267	104	31.1:1
Boeing Shanghai	China	681	358	25	14.3:1
ST Aerospace Services	Singapore	1,393	595	39	15:1
HAECO	Hong Kong	4,400	3,500	117	29.9:1
Aerovias de Mexico ^b	Mexico	899	592	45	13.1:1
Mexicana MRO	Mexico	633	488	18	27.1:1
NAYAK	Germany	190	165	2	82.5:1
Delta Airlines (Atlanta)	United States	8,843	1,531	4,804	1:3.1
American Airlines (Tulsa)	United States	6,500	604	2,760	1:4.6
TIMCO (Greensboro)	United States	984	515	506	1:1

Source: CRS Analysis of FAA repair station database (<http://av-info.faa.gov/repairstation.asp>) as of November 10, 2012.

- a. Non-Certificated Mechanics and Repairmen: Certificated Mechanics rounded to the nearest tenth.
- b. Mexico City facility only.

This analysis largely confirms the ratios cited by the Transportation Workers Union in its report. Two important considerations for making meaningful comparisons between domestic and foreign repair stations are not apparent in these data. First, workers at foreign locations may be certificated by foreign regulators, and the requirements for such certification may or may not be comparable to those imposed by FAA. Second, foreign repair stations may work on aircraft from many countries, and a small number of FAA-certificated mechanics may simply reflect that the repair station does relatively little work on U.S. aircraft. This may explain why facilities in El Salvador have relatively more FAA-certificated mechanics than those in China. However, data on the specific aircraft maintained at each facility are not readily available.

English Language Concerns

Besides potential concerns over the levels of training and supervision of repair station aircraft maintenance workers, several reports have raised concerns over the general lack of English language proficiency among repair station workers. As previously noted, language barriers may

⁵⁸ Transportation Workers Union of America, AFL-CIO, Air Transport Division, *Aircraft Maintenance in America: Who Is Fixing My Airplane?*, Hurst, TX, March 3, 2011, p. 5.

be a specific concern among foreign repair stations in developing countries like El Salvador, where English as a second language is not commonly taught, as opposed to Europe, where English is routinely offered in education programs.

FAA requires demonstrated English proficiency for certificated mechanics and repairmen. As part of its certification testing, applicants are required to demonstrate they can read, speak, write, and comprehend spoken English language. Applicants are required to read from and provide a written interpretation of a technical manual, such as an aircraft maintenance manual. These requirements apply to mechanics and repairmen seeking certification at foreign as well as domestic repair stations. Repair stations are required to ensure that supervisors and inspection personnel who review repairs and maintenance understand, read, and write English, but there is no formal requirement that these workers have any specific English-language skills.

However, as previously noted, FAA certification is not required to work at a repair station, and FAA has no formal regulations regarding the number of certificated personnel at foreign repair stations. Lack of English proficiency may be one reason only a relatively small percentage of foreign repair station workers obtain FAA certification. Language may be a greater barrier to certification in developing countries like El Salvador, where many workers may lack English proficiency, than in Europe, where schoolchildren routinely learn English.

English has become the international standard language for aviation, particularly with respect to air traffic control communications. Increasingly, it is becoming the standard language for aircraft maintenance as well, with maintenance manuals issued by airframe and engine manufacturers worldwide being published solely in English and fewer airlines customizing maintenance documents or translating them into other languages. Increasingly, computerized aircraft systems with English-only interfaces, including maintenance interfaces, require a working knowledge of technical English to diagnose and repair advanced avionics. Thus, technological advancement is also driving the need for English language proficiency to some degree. That said, aircraft maintenance also involves many less technical tasks, such as interior refurbishing and airframe painting, which may not require English-language skills. It is often these less skilled jobs for which foreign repair stations offer the greatest cost savings compared to domestic repair stations. Consequently, limited English language skill among workers at these facilities may not, by itself, be cause for significant concern.

The level of language proficiency among skilled maintenance workers at these foreign repair stations has not been systematically studied. Moreover, repair stations have no obligation to require or report English language proficiency, except among their FAA-certificated mechanics who exercise inspection authority and sign off on repairs to U.S.-registered aircraft.

Drug and Alcohol Testing and Substance Abuse Programs

In the past, regulation did not specifically require foreign repair stations to implement drug and alcohol testing programs required of workers in safety-sensitive positions that perform work either directly or by contract to U.S. air carriers. Many foreign countries impose their own drug and alcohol testing programs at foreign repair stations, as the International Civil Aviation Organization (ICAO) specifically defines inclusion of all safety-related positions in drug and alcohol testing programs in its aviation safety standards. ICAO has been working with countries

around the world to achieve greater harmonization with respect to the administration of drug and alcohol testing programs throughout the aviation industry.⁵⁹ ICAO has also published guidance materials to aid countries in developing policies to prevent substance abuse in the aviation workplace.⁶⁰ Despite international efforts to achieve global harmonization with respect to drug and alcohol testing and substance abuse prevention across the aviation industry, privacy laws and other limiting factors may contribute to some differences between drug and alcohol testing programs and policies in the United States and those in countries where foreign repair stations are located.

Legislative Action and Policy Considerations

Congress has shown interest in the oversight of foreign repair stations for more than a decade. Vision 100—Century of Aviation Reauthorization Act (P.L. 108-176) directed FAA to develop an oversight plan and implementation schedule to strengthen oversight of domestic and foreign repair stations and to ensure that FAA-certified foreign repair stations are subject to an equivalent level of safety, oversight, and quality control as domestic repair stations.

As noted in this report, reviews of FAA's progress toward meeting these objectives have found that several concerns remain. Reflecting these concerns, Congress included provisions related to the oversight of foreign repair stations in the FAA Modernization and Reform Act of 2012 (P.L. 112-95), which was enacted in February 2012. Specifically, Section 308 of the act requires

- FAA to establish and implement a safety assessment system for all repair stations approved under 14 C.F.R. Part 145 by February 14, 2013, with assessments based on the type, scope, and complexity of work performed;
- FAA to ensure that foreign repair stations are subject to appropriate inspections consistent with existing U.S. requirements;
- That agreements with foreign aviation authorities or other foreign government agencies provide an opportunity for FAA to conduct independent inspections of foreign repair stations when warranted by safety concerns;
- FAA to notify congressional oversight committees within 30 days of initiating formal negotiations with foreign governments on new maintenance safety or maintenance implementation agreements;
- FAA to issue an annual report describing improvements to identify and track where air carrier (14 C.F.R. Part 121) maintenance is performed; a staffing model regarding the number and geographic placement of FAA inspectors; inspector training; and a quality assessment of FAA and foreign authority inspections performed under existing agreements;
- FAA to request that all member countries of the International Civil Aviation Organization establish drug and alcohol testing programs encompassing all

⁵⁹ International Civil Aviation Organization (ICAO), Aviation Medicine (MED) Section, *Related ICAO Resolutions: A33-12: Harmonization of drug and alcohol testing programmes*, available at http://legacy.icao.int/icao/en/med/MED_resolutions.html.

⁶⁰ International Civil Aviation Organization (ICAO), *Manual on Prevention of Problematic Use of Substances in the Aviation Workplace* (Doc 9654-AN/945), First Edition, 1995. Order No. 9654, Montreal, Quebec, Canada.

- safety-sensitive maintenance workers that perform work on commercial air carrier aircraft;
- FAA to publish a proposed rule by February 14, 2013, to require drug and alcohol testing programs at all Part 145 repair stations that service Part 121 aircraft, consistent with the laws of the country where the work is performed; and
 - FAA to conduct annual inspections at all foreign repair stations consistent with obligations under international agreements.

Policy Implications

While U.S. airlines are increasingly sending aircraft overseas for major repairs and overhauls, highly skilled maintenance workers in the United States working on foreign aircraft have helped the United States retain a positive trade balance of aircraft maintenance work in the globalized MRO industry. Increasing competition in this field coupled with growing opportunities for advanced technical training overseas may reduce this advantage in the future. At the same time, however, the trend of maintenance offshoring may be offset to some degree by rising labor costs in developing countries that could diminish their comparative cost advantage. In this regard, improved data reporting and collection by FAA and BTS would assist in analyzing MRO outsourcing and understanding the movements and trends.

Although policymakers often raise the prospect of restrictive safety measures and additional inspections as a means to curtail the loss of American jobs to offshoring, applying such approaches to the aviation MRO industry could lead to reciprocal actions that could affect both maintenance work performed on foreign aircraft within the United States and U.S. companies that operate or have a stake in MRO facilities outside the United States. ARSA noted that many U.S. companies have repair stations internationally, estimating that about 80 foreign repair stations are either wholly or partly owned by U.S. firms. Additionally, ARSA points out that several international companies have MRO facilities within the United States.⁶¹ Thus, globalization of the MRO industry makes it increasingly difficult to apply effective trade actions as a means to protect U.S. jobs.

No solid evidence exists that the use of foreign repair stations to maintain U.S. air carrier aircraft has eroded airline safety. Safety concerns raised regarding work performed by foreign repair stations over the past decade have largely been anecdotal, and detailed studies have not identified specific indications that outsourcing maintenance to foreign MROs has increased risk. Nonetheless, examination of maintenance offshoring practices reveals several potential policy implications both for U.S. jobs and for airline safety.

⁶¹ *Foreign Repair Stations: The Critical Need for Their Existence and the Global Nature of the Aviation Maintenance Industry*, Testimony of Marshall S. Filler, Managing Director and General Counsel, Aeronautical Repair Station Association (ARSA), Before the Senate Subcommittee on Aviation Operations, Safety and Security, Committee on Commerce, Science, and Transportation, United States Senate, June 20, 2007, Aeronautical Repair Station Association, Alexandria, VA.

Implications for Domestic Jobs

With regard to implications for domestic jobs, it appears that the United States has maintained a positive balance of trade in aircraft MRO largely as a result of its superior technological skills and training, positioning it as a global leader in high-skill, high-value maintenance and repair. As such, the United States potentially stands to gain from increasing globalization of the MRO industry. The greatest threat to such standing does not appear to be primarily from the offshoring of heavy maintenance, but rather from the possibility that other countries may invest heavily in advanced training and technical capabilities to compete more directly with the United States on high-value engine and component repair and overhaul operations.

Implications for Aviation Safety

With regard to safety, FAA has limited resources to allocate to oversight and inspection of foreign repair stations, thus necessitating reliance on foreign regulators and airline auditors to conduct routine oversight of foreign repair facilities. Realigning the FAA inspector workforce to allow for increased oversight of repair stations located in foreign countries may help respond to the increased utilization of foreign repair facilities by U.S. air carriers. This may involve selecting and assigning FAA inspectors based on proficiency in specific foreign languages and familiarity with foreign cultures. Despite a congressionally mandated examination of FAA's inspector staffing model by the National Research Council, which was completed in 2007,⁶² further action may be needed to more specifically address realignment of the FAA inspector workforce to better reflect changes in airline maintenance practices.

The lack of English-language proficiency among foreign repair station workers is a particularly complex issue which may deserve more detailed study. Most discussion of this issue has focused broadly on aviation maintenance without looking in detail at the types of jobs, the skills performed, and the resource requirements, including written reference materials, needed to complete these tasks. Such detailed analysis could determine where additional English language skills may be most acutely needed among foreign repair station personnel and possibly lay the groundwork for FAA regulations.

Setting regulatory standards regarding the total numbers and ratios of FAA-certified mechanics and repairman to uncertified maintenance workers as a condition of 14 C.F.R. Part 145 approval may be a means to address concerns about the lack of FAA-certificated mechanics at some foreign repair facilities. Such standards might need to take into consideration both the overall volume and the percentage of repair station work that is performed on U.S. airline aircraft to ensure that any additional regulatory requirements are appropriately directed at those repair stations where extensive work on U.S. air carrier aircraft is performed. This and other regulatory considerations may require more extensive reporting requirements for air carriers to allow FAA to better assess where the numbers of FAA-approved mechanics may be insufficient as well as where regulatory oversight activities may need to be targeted.

⁶² National Research Council, *Staffing Standards for Aviation Safety Inspectors*, ed. William C. Howell and Susan B. Van Hemel (Washington, DC: The National Academies Press, 2007).

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