

TRANSPORTATION AND DEFENSE EQUIPMENT

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AIRCRAFT

The global aircraft industry manufactures new and rebuilt aircraft for the commercial and general aviation markets. For discussion of military aircraft, see also **Defense and Armaments**.

INDUSTRY SNAPSHOT

Civil aircraft production is dominated by the commercial market, supplying the jets and turboprops used by the world's passenger and cargo airlines. As of the mid-2000s, just two manufacturers—Boeing in the United States and Airbus S.A.S. in France—have controlled nearly the entire market for commercial aircraft for more than a decade. This lead was secured primarily by manufacturing medium and large jets for 100 or more passengers, the industry's most lucrative and capital-intensive segments. Aircraft manufacturers noted the rising demand for large-capacity, wide-body planes and expected that the average number of seats per plane would increase to 240 by 2015. They expected that Asian countries would help drive this trend with a 356-seat average capacity per plane by 2015. Airbus was set to deliver its 555 passenger A380 in 2008.

The huge costs and risks of aircraft manufacturing encouraged business consolidation and a proliferation of international joint ventures in what has been termed a "borderless industry." Few countries could be considered self-sufficient in production, and even for those that could, most competitors in the industry pursue multiple cross-border ventures in order to keep costs down and draw on the special competencies and efficiencies of firms around the globe.

Globally, the industry experienced continued growth in the early 2000s. Boeing's World Air Cargo Forecast predicted an annual expansion rate of 6.2 percent through 2023, tripling the levels of overall air traffic. Strong growth was reported in international trade, with the most reported in the Asia-Pacific region. Traffic in North America and within Europe was expected to realize below average increases. The

U.S. firms Cessna Aircraft Co. and Raytheon led the continuing strong surge in sales in the general aviation segment. The U.S. industry reached US\$147 billion in 2003 sales. That year, Boeing, with about 280 units, and Airbus, with about 300 units, produced a combined US\$33 billion in aircraft. These had a per-unit value of US\$50 million or more, according to *Fortune*. For the first half of 2004, the companies delivered a combined 312 aircraft. According to researchers from the Teal Group, US\$421 billion in aircraft will be built by 2012.

ORGANIZATION AND STRUCTURE

Although the field includes all types of aircraft, including large transports, hang gliders, rotary-wing aircraft (such as helicopters), and balloons, a few conglomerates specializing in civil transports and military aircraft dominate the global aircraft industry. Since most modern aircraft are incredibly complex (the Boeing 747, for example, has 6 million parts), a worldwide network of approximately 400 subcontractors supplies major structures and subassemblies, such as wings and fuselages, to manufacturers of finished aircraft. These subcontractors are supplied, in turn, by up to 4,000 firms that manufacture components or raw materials. Parts that differentiate a product, or those strongly identified with a company, are usually produced in-house due to their strategic and competitive importance.

A strong customer base and careful order book management are needed in order to recoup high development costs for airliners or large business jets. Standards for safety, quality, and value, among other things, are obviously crucial. To break even on the design and manufacture of a new airliner, for example, a company like Boeing or Airbus must receive an order for, receive the money for, and provide delivery of hundreds of airliners globally. Because that process can take years, many orders fall through. Thus, the industry gauges not just orders and transactions but completed orders, and otherwise has made an art of order book management. In 2001 alone, Airbus experienced 101 order cancellations (90 percent of which were due to company bankruptcies). Some of these cancellations may yet reenter the Airbus order book and become part of the company's healthy backlog.

The industry is not only cyclical, it relies on a small number of consumers, mostly airlines and governments. Due to long lead times and backlogs, airlines may hastily buy aircraft in advance of their true needs to keep from missing out on model availability in future periods or to avoid availability at much higher prices.

Airline specifications and regulations also affect the design, marketing, and sales of passenger aircraft. Because safety is a highly visible priority in aviation, no civilian operator would readily buy an aircraft that has not been certified by an agency such as the Federal Aviation Administration (FAA) in the United States, the Civil Aviation Authority (CAA) in the United Kingdom, or the Interstate Aviation Committee (IAC) in the Commonwealth of Independent States. In 1993 the Airbus A330 became the first aircraft to be certified simultaneously in the United States and Europe. To enhance the marketability of their aircraft, Airbus and Boeing also sought extended range certification. This extension would allow flights on routes within 180 minutes' flying time of diversion airports, rather than 60 minutes, the standard for most twin-engine aircraft. Boeing and Airbus accomplished this objective for their A330 and 777 models.

For general aviation, the 1990s were a period of consolidation. Companies either streamlined their production (as in the case of Beech Aircraft Corp.), were acquired by large conglomerates (for example, the business jet operations of British Aerospace were acquired by Raytheon Co.), or both (Cessna was acquired by Textron). In 1997 two of the industry's largest producers, Boeing Company and McDonnell Douglas Corporation, merged. Other well-known companies, such as Piper Aircraft Corp. and Fairchild Aircraft in the United States, as well as Fokker N.V. of the Netherlands, filed for bankruptcy during this period.

Ultralight aviation grew out of a hang gliding resurgence in the 1970s. In 1976 a U.S. adventurer attached a golf-cart engine to a hang glider, creating an inexpensive way to go aloft. Like the earliest flying machines, ultralights and homebuilts—sophisticated craft that come in a kit for home assembly—became the province of tinkerers and serious amateurs. These small machines made aviation more affordable and more accessible for its proponents. They are available for a fraction of the cost of factory-built aircraft (typically less than US\$5,000) and are governed by a different set of FAA standards (such as a 254 lb. total weight limit and a five-gallon fuel tank limit). In the mid-1990s approximately 10,000-15,000 ultralights were in existence in the United States. Although not as lucrative as other segments, the ultralight/homebuilt industry has been both the source and beneficiary of many innovations. Less-developed countries such as Peru have actually used ultralights as military training craft.

Rotorcraft, helicopters, and similar craft accounted for about 3 percent of the civil aircraft market in the late 1990s. At that time, worldwide drops in military spending negatively affected the civil helicopter market, for the military dumped its surplus rotorcraft into the civil market, reducing sales. In the civil helicopter sector, Bell Helicopter-Textron shared healthy fractions of the market with Eurocopter, MD Helicopters, and Robinson (which eschewed turbines for piston engines in its entire product line). Total civil helicopter

deliveries averaged approximately 500 units per year with a value of US\$1 billion in the late 1990s. In the early 2000s, analysts expected slightly less favorable results, especially for rotorcraft manufacturers that failed to specialize in niche markets or had not managed to merge with, or been acquired by, other producers.

With an aging fleet and handicapped by older aircraft-manufacturing technology, the Commonwealth of Independent States (CIS) had the potential to become an important market for aircraft. China was expected to surpass Japan as the largest international aircraft market early in the twenty-first century. Eastern Europe, Asia, and the Pacific Rim, along with China, were expected to be growth markets. Similarly, demand in Central and South America rose and aircraft makers expect this region to be a major customer in the early 2000s.

Asian carriers in particular seem promising. Boeing predicted that they would purchase US\$232 billion in new aircraft by the year 2010; indeed, the world market was predicted to be worth US\$857 billion. The long-term commitment required by aerospace developers seemed philosophically compatible with traditional Asian business strategy. The region has a large market and a large supply of skilled workers—crucial in an industry with high quality standards. Joint ventures have proliferated in the region, as local manufacturers sought experience and American and European firms sought a competitive marketing edge. Singapore, Indonesia, Taiwan, China, and South Korea all have aircraft manufacturing programs. However, the lingering recession in Japan and in other Far East countries in the early 2000s was thought to be an unfavorable factor in the growth of demand for new aircraft.

BACKGROUND AND DEVELOPMENT

Long before aircraft with viable commercial applications were developed, aviation was the province of dreamers and idealists. The quest for flight has been documented as early as the first century in Ovid's tale of Daedalus and Icarus; according to mythology, Icarus made wings of wax and bird feathers, flew too close to the sun, and died. The brothers Joseph Michelle and Jacques Etienne Mongolfier introduced a passenger-carrying hot air balloon in France in 1783. Military tacticians, always searching for the "high ground," employed the balloon as an observation post as early as 1794 during the battle of Maubeuge in France. Not surprisingly, in 1910 a form of balloon called an airship, or dirigible, was the first aircraft to be used for commercial aviation.

Numerous isolated eccentrics tinkered with gliders in the nineteenth century. Before falling to his death in 1896, Otto Lilienthal studied birds and found the secret of flight to be in the curved wing. He and the Scottish engineer Percy Pilcher, who was also killed experimenting with gliders, laid the foundation for the Wright brothers' invention of the airplane at the turn of the twentieth century. Lilienthal also received credit for manufacturing the first aircraft for sale, the Lilienthal Type 11 glider.

Many others had sought to build powered aircraft, too often constructing machines with flapping wings, called “ornithopters.” On December 17, 1903, bicycle makers Orville and Wilbur Wright earned credit as the first to produce an aircraft capable of powered, sustained, and controlled flight. Such a lofty honor had been coveted around the world. Thus, the early development of the “flying machine” was hindered by bickering and fierce legal battles. For example, Gabriel Voisin, who along with his brother, Charles, was the first to build aircraft in France on a commercial basis, scoffed at the influence of both the Wright brothers and other aviation pioneers.

A company founded by Glenn Curtiss made the first commercial sale of an aircraft in 1909 to the Aeronautic Society of New York. In the same year, one of the Wright brothers succeeded in meeting U.S. Army specifications for an aircraft and sold it to the government for US\$30,000. The Wrights promptly sued Curtiss for patent infringement, virtually freezing the development of the aircraft industry in the United States until World War I. After the war, U.S. Army war surplus Curtiss JN-4 “Jenny” trainers, along with the de Havilland Moth, manufactured in Great Britain, would carry the postwar barnstorming craze across the country. The Piper Cub, introduced in 1937, quickly became the best-selling one-engine plane of all time in general aviation.

Although Leonardo da Vinci had sketched a helicopter design in 1483, the first sustained helicopter flight was not achieved until 1935, with a coaxial model built by Louis Breguet and René Dorand in France. Within the next five years, Igor Sikorsky had perfected a single-rotor type of helicopter in the United States, opening the door for many practical applications.

The early companies formed by the pioneers eventually merged with and were acquired by larger concerns. For example, the Wright Company, formed in 1909 when a group of New York investors bought the Wright brothers’ patents for US\$100,000 in cash, was sold to another group in 1915. That group then merged with the Glenn L. Martin companies to form the Wright-Martin Aircraft Corporation, which later became the Wright Aeronautical Company, which merged in 1929 with the Curtiss Aeroplane and Motor Company to form the Curtiss-Wright Corporation, controlled by North American Aviation.

Larger conglomerates dependent upon government support continued to dominate the aircraft industry throughout World War II and the postwar period. The First World War had demonstrated the possibilities of aircraft in wartime; by World War II, aircraft had become an integral part of modern warfare. Many of the phenomenal advancements in aircraft design—jet engines, swept-back wings, electronic flight controls, and composite materials—were funded by governments in wartime. Air Force One, a Boeing 747 that serves as both the U.S. president’s air transport and mobile command post in the event of a war, illustrates how important aircraft have become to national security. The technological improvements in military aircraft have been accompanied by a proportional increase in their price tags; a typical 1945 fighter plane cost about US\$51,000 (or about US\$430,000 in 1998 dollars). By the 1990s, the F-16 jet fighter, a staple of

the U.S. Air Force, was selling for approximately US\$25 million.

Two new airliners developed in the 1960s, the wide-body (“jumbo”) jet and the supersonic transport (SST), met with much different degrees of success. The Boeing 747, the first jumbo jet, which started service on February 9, 1969, was warmly welcomed and widely purchased. Meanwhile, economic and environmental concerns caused the United States to cancel its SST program. The Anglo-French SST (the Concorde) and the Soviet SST (the Tu-144) entered service in 1976 and 1977, respectively. Due to high fuel costs and other concerns, the airlines did not embrace the Concorde, and production ceased in 1979. Meanwhile, in the Soviet Union a series of disastrous crashes halted development and production of the Tu-144.

Asian countries such as South Korea, Malaysia, Vietnam, Indonesia, and the Philippines ordered numerous new planes, as their economies grew rapidly in the mid-1990s. But economic problems began to plague East Asian countries in the late 1990s, causing devaluations of their currencies and forcing them to reconsider their aircraft orders and projects. In early 1998 Philippine Airlines canceled its order of four 747-400 planes from Boeing. Latin America also emerged as a thriving market for the aircraft industry, with orders for US\$4 billion worth of planes announced in 1997. Because of their growing economies, Asian and South American countries made up the largest new growth markets for such aircraft. But South Korea, Indonesia, Malaysia, and even Japan experienced shrinking economies in the late 1990s, leaving short-term expansion of the East Asian market far from certain.

Though constantly under the threat of quick market erosion, from the mid-1990s through 2001 the industry reported fairly strong sales overall. Results differed considerably by segment. By the end of that period, a cyclical slowdown—evident early in 2001 with apparent airline overcapacity and confirmed in late 2001 with the September 11 terrorist attacks—all but guaranteed contraction in the aircraft industry in 2002. The attacks spurred a heavy round of aircraft order cancellations worldwide in the following months. In 2002 some of the cancellations were rescinded as passenger traffic recovered. This prompted some analysts to quietly call for a modest recovery in many segments in 2003. Passenger bookings subsequently rebounded, and excess plane capacity was absorbed or retired, even as the SARS scare in Asia and the instability of many world regions also contributed to the decline of passenger air travel.

CURRENT CONDITIONS

Taking into account other factors, commercial sales were accurately predicted to rise in the 2000s due to the need to replace older, less fuel-efficient aircraft that did not meet new international noise and emissions standards. During a climate-change conference in Kyoto, Japan, United Nations participants laid the groundwork for much stricter aircraft emission regulations to take effect in the early 2000s, under the Kyoto Protocol. The European Union established its own standards, which mandated a 16 percent reduction of nitrous oxide emissions from all new-model engines beginning in