Helicopters

INDUSTRIAL CODES

NAICS: 33–6411 Aircraft Manufacturing

SIC: 3721 Aircraft Manufacturing

NAICS-Based Product Codes: 33–64113014 and 33–64113017

PRODUCT OVERVIEW

No one knows how long humans have dreamed of flying, but this concept informed some of Western culture's earliest stories. Around the time BC became AD, the Roman poet Ovid told the tale of Daedalus and his son Icarus. The first storytellers as well as their audiences could see snow persisting on the highest mountain peaks during warm weather; clearly, air did not grow warmer with altitude, so the sun would not have melted the wax holding Icarus's feathers to his wings. This tale appeals to the emotions, not to reason.

A modern audience could note how the genius of Daedalus, using observation to mimic birds' wing shapes, was rendered irrelevant by his son's reckless behavior. Passion defeated by reality was a lesson that early would-be aeronauts repeatedly rediscover, frequently at a high price. This essay summarizes the history of helicopters.

Helicopters are aircraft characterized by large-diameter, powered, rotating blades. Such a craft can lift itself vertically by accelerating air downward at an angle. The helicopter is the most successful vertical takeoff and landing (VTOL) aircraft yet developed due to its relatively high efficiency in performing hovering and low-speed flight missions.

From the ancient literature cited above, we move forward more than fourteen centuries to the first designs of what human-created flight might look like, and waiting for us is Leonardo da Vinci. His earliest written speculation on human-powered flight dates from 1473, when he was twenty-one, and his notebooks demonstrate that this was a lifelong fascination. Many artists of this period designed theater sets; Andrea del Verrocchio, to whom the young Leonardo was an apprentice, made such sets for the Medici family, and illusionist flying machines were often involved.

Leonardo's first sketch of such a device dates to 1478; today, it would be called a hang glider. The first appearance of a helicopter in Leonardo's notebooks dates to 1490, where a depiction of a large central screw-like device was designed to measure about thirteen feet in diameter. Leonardo intended it to be made of reed and covered with taffeta to make a light, resilient wing. This helicopter is shown as powered by four men who ran on the craft's platform around the central shaft, pushing a bar that would cause the spiral to turn. The helicopter would, at least theoretically, bore its way through the air like a giant corkscrew.

Even as a might-have-been, Leonardo's continuous spiral airfoil offers fascinating possibilities. To find those possibilities realized, we must travel forward four centuries more, to a chilly, windy beach called Kitty Hawk in North Carolina. On December 17, 1903, Wilbur and Orville Wright's 750-pound plane launched from a railroad track at less than seven miles per hour, attained an altitude of

perhaps ten feet, and landed about twelve seconds later, having traveled 120 feet. This modest beginning led to a new world in which gravity, while impossible to ignore, could be successfully challenged and, less than seventy years later, overcome as humans traveled to and landed on the moon.

A few decades more and we have arrived at the moment where sufficient power combines with essential materials and human daring. The year is 1939; the place, a Connecticut field; and the person in the well-worn fedora, Igor Ivanovitch Sikorsky, born in Russia and emigrated to the United States in his thirties.

Everything about Sikorsky's VS-300 was bare-boned: the cockpit was only a seat in front of the exposed 75-horsepower engine; belts and pulleys drove the blades; the vertical rotor spun at the end of a spar.

This ungainly machine was an attempt to perfect the helicopter, which Sikorsky and others believed would be the aircraft that brought flight to the masses. The vision was one of backyard and rooftop helipads with commuters taking to the air rather than the road. But engineers had yet to perfect the helicopter. Prototypes lifting off the ground proved too cumbersome for regular service.

The idea of the helicopter was inspired not by nature but the screw discovered by Archimedes approximately 2200 years ago. A screw pump can push water up an incline and a propeller screw can push against water to move a ship forward. Why couldn't a large enough screw pull a machine into the air?

Like hundreds of others in aviation, Sikorsky built on the work of others. In 1919 the Spanish aircraft engineer Juan de la Cierva y Cordonia was studying how aircraft stall. As a propeller pulled a plane down the runway or through the air, the rotor turned, producing lift. Even if the engine failed in flight, the rotor would continue to turn, providing enough lift to enable a slow, controlled descent. Cordonia used this phenomenon to create a free-wheeling rotor he used as a crucial part of what he called his *autogiro.*

The first sustained helicopter flight was not achieved until 1935, with a coaxial model built by Louis Breguet and René Dorand in France. Building partly on that attempt, Sikorsky took out the tandem rotors that canceled the counter-rotation (known as *torque*) in the French design and used a single main rotor for lift. This greatly simplified the mechanism and made controlling the craft much easier.

The first flight of Sikorsky's VS-300 was something less than astonishing. On Sept. 14, 1939, the craft cleared the ground by just a few inches, probably due to the rotor blowing air downward, and the whole event lasted 10 seconds. This was partly intentional, since the craft had been tethered to the ground in case anything went wrong. For successive flights, the engineers fixed a glitch that shook the machine violently when the rotors whirred at speed and, by November, short one-minute hops were possible.

Test flights through the spring and summer of 1940 helped Sikorsky and his team improve the manner in which aerodynamics applied to the helicopter. They also began practicing some of the three-dimensional feats that make helicopters so useful: landing on a dime, hovering over a single point, even throwing down a rope ladder for a rescue.

Once the control problems were better understood, Sikorsky and his team were able to eliminate first one and then both of the horizontal auxiliary rotors, opting instead for changing the pitch of the main rotor to control longitudinal and lateral motion. The modern helicopter was born.

> The helicopter is probably the most versatile instrument ever invented by man. It approaches closer than any other to fulfillment of mankind's ancient dreams of the flying horse and the magic carpet.—Igor Ivanovitch Sikorsky, comment on twentieth anniversary of the helicopter's first flight Sept. 13, 1959

MARKET

The animation company Hannah-Barbera created *The Jetsons* in the early 1960s. Set in an unspecified future, everyone who wants one has access to a flying car, very much in the spirit of Sikorsky's dream. In the real world, military and other interests reserved helicopters for highly specialized purposes.

Although U.S. forces gained some experience with helicopters late in World War II, the first substantial use of the vertical-takeoff craft came in the Korean War. Between 1950 and 1953 helicopters performed casualty evacuation, search and rescue, troop insertion, cargo transport, and reconnaissance. In 1950 General Douglas MacArthur requested more helicopters for use as organic aircraft within division, corps, and army headquarters units. U.S. Marine Corps units also used helicopters as airlift and combat support. Perhaps the greatest contribution helicopters made to the war effort in Korea came in transporting wounded soldiers to Mobile Army Surgical Hospitals for emergency medical care. By the end of the Korean War, the U.S. military was committed to developing the helicopter's potential for nearly every possible mission.

After the war, helicopter designers concentrated on developing powerful craft that could carry greater payloads over longer distances. Sectors such as oil exploration came to depend on the economical transportation ability provided by helicopter technology. The military concentrated on making helicopters essential to warfare.

The French used helicopters to patrol and dominate large territories in the Algerian War foreshadowing the U.S. Army's airmobile concepts typifying the Vietnam War between 1964 and 1973, when the army created air cavalry divisions with helicopters outfitted to specialize in assault, attack, heavy and medium transport, command and control, search and rescue, and medical evacuation. Even the last images of U.S. involvement in Vietnam included helicopters evacuating embassy personnel and refugees from the roof of the U.S. embassy in Saigon (later, Ho Chi Minh City) as the South Vietnamese government collapsed in March, 1975.

Civilian use of helicopters spread widely after the Vietnam War. The speed, mobility, and vertical takeoff and landing that made helicopters attractive to military forces also appealed to police, emergency services, and firefighters, especially in remote areas. Law enforcement helicopters from federal to local levels assisted ground units in surveillance and pursuit operations. Emergency service helicopters made dramatic rescues of hapless hikers and climbers. Helicopters enhanced firefighting efforts whether in large-scale wildfires or in combating hazardous industrial fires.

Though military and commercial aircraft manufacturers dominate the industry in the early twenty-first century, American companies also produced many aircraft for the general aviation and the helicopter market segments, which included fixed wing aircraft and rotorcraft for business transportation, regional airline service, recreation, specialized uses such as ambulance service and agricultural spraying, and training. American manufacturers historically produced approximately 60 percent of the world's general aviation aircraft and 30 percent of the helicopters.

Sales and exports of U.S. civil helicopters surged in 2005 to record levels, according to the U.S. Aerospace Industries Association (USAIA). In its aerospace industry annual review, the trade group reported civil helicopter sales jumped from $515 million to a record $750 million. The U.S. industry shipped 120 more civil helicopters in 2006 than it did in 2004.

Civil helicopter exports also reached record levels, rising 57 percent to $490 million. "Used civil aircraft exports rose 31 percent from already high levels to $2.8 billion," the USAIA said, "helping exports and the trade balance, but not resulting in new production."

According to Flight's HeliCAS database, a healthy 531 turbine helicopters were civil-registered in 2006. The leading helicopter makers also reported strong order backlogs and were planning higher production rates in 2007. While the helicopter industry was riding the same post-9/11 economic recovery that was boosting other sectors of commercial aerospace, it was also seeing strong growth in the offshore support sector, which was re-equipping after years of operating aging but depreciated helicopters. Growth in the law enforcement and emergency medical service sectors was also playing a part.

U.S. manufacturers shipped 4,088 units of complete civilian aircraft (fixed wing, powered craft; helicopters; and non-powered types of civil aircraft) in 2002, valued at approximately $34.7 billion. In terms of unit shipments, this figure represented a decrease from 2001, when the industry shipped 4,541 units valued at 41.8 billion, and from 2000 when shipments numbered 5,162 civil aircraft valued at $38.6 billion.

In use as aerial cranes, firefighting, air ambulances, crop-dusting, search and rescue, law enforcement, a host of military purposes, and the transport of the rich and famous, it may be more appropriate to ask where helicopters are not useful than to list where they are.

KEY PRODUCERS/MANUFACTURERS

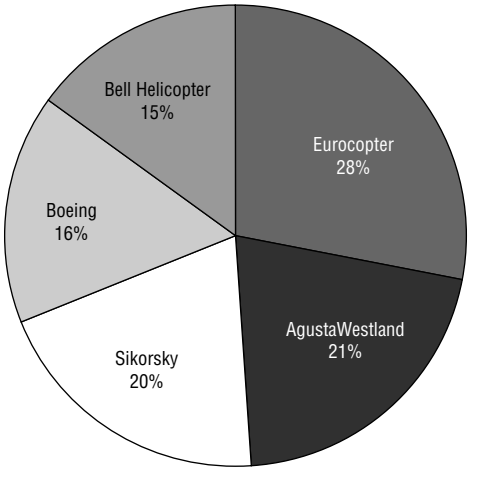
Five large-scale firms dominated the helicopter production field in the first decade of the twenty-first century, as can be seen in Figure 108. Each is profiled briefly below.

Eurocopter S.A. Europe's largest helicopter maker, Eurocopter, makes a full range of civilian and military helicopters and offers helicopter repair, maintenance, and overhaul services.

This premier manufacturer has four plants, two in France and two in Germany, and many offices worldwide. Eurocopter employed a workforce of 10,822 people pro-

FIGURE 108

Leading Helicopter Makers Worldwide, 2005



SOURCE: Compiled by the staff with data from "Leading Helicopter Makers Worldwide," *Market Share Reporter 2008,* early draft edition, page 536, The Gale Group. 2007.

ducing 57 percent of the civil market and 25 percent of the military market in the middle of the first decade of the twenty-first century. Eurocopter reported revenues of $2.6 billion in 2002. The European firm, with its vast product range, continues to significantly outsell its rivals, claiming to have captured 52 percent of the market in units in 2005 (twice as much as its nearest rival), and 46 percent by value. It has been first in the U.S. market during the period 2000–2005, with a more than 50 percent market share in the EMS, para-public, utility, and tourism sectors.

Like most of its competitors, Eurocopter increased its investment in the Asia Pacific market to the extent that by 2006, it claimed to have captured half of the civil and para-public market in Japan. Eurocopter announced the creation of a Japanese subsidiary in 2006 to coordinate the commercial network in that region. The European firm also views India as a strategic market, and plans to set up a local organization based in Bangalore.

Bell Helicopter Textron Inc. A subsidiary of Textron, the company makes commercial and military helicopters and tilt-rotor aircraft. Bell's commercial helicopters seat up to 15 passengers and include models designed for transport, emergency medical services, and search and rescue operations. Military models include the venerable UH-1Y *Huey,* a utility helicopter used for personnel and medical transportation; the AH-1Z Super Cobra reconnaissance/attack helicopter; the Eagle Eye Unmanned Aerial Vehicle (UAV); and the V-22 Osprey tilt-rotor (with Boeing). Bell also makes helicopters through joint venture Bell/Agusta Aerospace and provides repair, maintenance, and overhaul services.

Bell representatives claimed that the company achieved a 23 percent increase in civil helicopter shipments in 2005, compared with the previous year. It continues to build its new offerings on the foundations laid by its older models the Bell 210, a derivative of the Huey, which achieved FAA certification in 2005; and the 407X light single, a 407 refitted with Honeywell's new HTS900 engine and which is the basis for Bell's selection for the Armed Reconnaissance Helicopter (ARH) program—a 368-unit order that has given Bell a new lease of life.

Boeing Company. In 1916 William E. Boeing founded the Boeing Company, then called Pacific Aero Products, in Seattle, Washington. Until 1960 Boeing was only a designer and manufacturer of airplanes. After acquiring Vertol Aircraft Corporation, Boeing became a designer and manufacturer of helicopters as well. On September 21, 1961, the CH-47A Chinook helicopter took its first flight.

At the beginning of the twenty-first century, Boeing Company was the world's largest manufacturer of commercial jetliners and military aircraft, and was NASA's leading contractor. In 2006 its total revenues were $61.5 billion. Boeing Integrated Defense Systems, a division of Boeing Company, manufactures the Apache Longbow, the Chinook, and the Osprey helicopters for the military. This division employed 72,000 people and had revenues of $32.4 billion in 2006. Boeing's headquarters are in Chicago, Illinois.

Sikorsky Aircraft Corporation. Though its legendary founder is long gone, helicopters bearing his name still fly the skies. A subsidiary of United Technologies, Sikorsky Aircraft's military helicopters include the Black Hawk, used for troop assault, combat support, special operations, and medevac operations; and the Seahawk, used for submarine hunting, missile targeting, anti-surface ship warfare, and search and rescue.

The company claimed in 2006 to have logged double-digit growth for the prior three years, with dollar sales leaping from $100 million in 2001 to $600 million for civil aircraft deliveries in 2005. Chief Executive Officer Jeff Pino predicted that billings would be close to those of Eurocopter in 2007. Sikorsky continues to pursue new derivatives, such as the S-76D, scheduled for certification by end-2008. With a maximum takeoff weight of almost 6.6 tons, other features include new composite main and tail rotors offering a 2 decibel noise reduction and a new PW210S engine featuring a dual-channel FADEC and 10 to 20 percent extra power in comparison with the current engine.

The company was also excited about the new Thales Topdeck cockpit, which was being installed on civil helicopter for the first time in 2007. Derived from the cockpit developed for the A380 super jumbo, it features four 6 x 8-inch multifunction screens, an integrated interactive flight management system, synthetic vision interface, and a trackball to interact with the moving map display. Also for the first time on a helicopter, the vehicle includes integrated backup instrumentation giving altitude, attitude, and speed.

AgustaWestland N. V. One of the world's largest helicopter manufacturers, this company produces a wide range of high-performance rotorcraft for civil and military markets. Of 92 helicopters it delivered in 2004, 66 went to commercial customers. Formed by combining two leading European helicopter manufacturers, AgustaWestland has operations in Italy (near Milan), the United Kingdom (near Somerset, England), and the United States (Fort Worth, Texas, and Philadelphia, Pennsylvania).

AgustaWestland bought out Bell Helicopter's 25 percent stake in the medium twin-turbine AB139 in November, 2005, to improve support and increase sales. Instead of Bell assembling the helicopter in Amarillo, Texas as originally planned, AgustaWestland was expanding its Agusta Aerospace (AAC) subsidiary in Philadelphia, Pennsylvania, to establish production of the AB139 for the North American market. AAC already manufactures the single-turbine A119 and U.S. production of the AB139 was to begin by the end of 2006. AgustaWestland, based at Cascina Costa, Italy, is the second-largest helicopter manufacturer in revenue terms with sales of €2.54 billion in 2004, but around 90 percent of its business is defense. The company responded to the strong interest from the U.S. market by announcing a second production line in Philadelphia, boosting production capacity to 50 units per year. This line, like its twin in Vergiate near Milan, will be directly supplied with structural elements produced by PZL in Poland and TAI in Turkey.

MATERIALS & SUPPLY CHAIN LOGISTICS

Although not quantified until long after the Wright brothers skidded and soared over Kitty Hawk's sand dunes, the ability to fly was eventually rendered as lift plus thrust having to exceed mass (known on Earth as weight) plus drag. All aircraft design must struggle with this reality. The first powered aircraft were largely paper and thin cables, but engineers continue to explore how machines, especially helicopters, can fly more with less.

Some aircraft of composite materials began to appear in the late 1930s and 1940s; these were usually plastic-impregnated wood materials. The largest and most famous example of this design is the Duramold construction of the eight-engine Hughes flying boat, popularly known as the *Spruce Goose.* A few production aircraft also used Duramold materials and methods.

Fiberglass, fabrics made up of glass fibers, were first used in aircraft in the 1940s and became common by the 1960s. Composite is the term used for different materials that provide strengths, light weight, or other benefits not possible when these materials are used separately. They usually consist of a fiber-reinforced resin matrix. The resin can be a vinyl ester, epoxy, or polyester, while the reinforcement might be any one of a variety of fibers, ranging from glass through carbon, boron, and several other proprietary types.

To these basic elements, strength is often increased by adding a core material, making a structural sandwich. Core materials such as plastic foams (polystyrene, polyurethane, or others), wood, honeycombs of paper, plastic, fabric or metal, and other materials, are surrounded by layers of other substances. This method has been used to create, for example, Kevlar, used in aircraft panels, and Lucite, superior to glass for aircraft windows and canopies.

By the twenty-first century, almost all helicopter parts include composites. The airframe, or fundamental structure, of a helicopter can be made of either metal or organic composite materials, or some combination of the two. Higher performance requirements encourage the designer to favor composites with higher strength-to-weight ratio, often epoxy (a synthetic resin) reinforced with glass, aramid (a strong, flexible nylon fiber), or carbon fiber. Typically, a composite component consists of many layers of fiber-impregnated resins, bonded to form a smooth panel. Tubular and sheet metal substructures are usually made of aluminum, though stainless steel or titanium is sometimes used in areas subject to higher stress or heat. To facilitate bending during the manufacturing process, the structural tubing is often filled with molten sodium silicate. A helicopter's rotary wing blades are usually made of fiber-reinforced resin, which may be adhesively bonded with an external sheet metal layer to protect edges. The helicopter's windshield and windows are formed of polycarbonate sheeting.

Modern helicopter engines use turbines rather than pistons and are purchased from an engine supplier. The helicopter manufacturer may purchase or produce the transmission assembly, which transfers power to the rotor assembly. Transmission cases are made of aluminum or magnesium alloy.

DISTRIBUTION CHANNEL

Regardless of the kinds of machines in which they are used, most aircraft parts have common origins and distribution channels.

The American aircraft industry can be divided into four segments. In one segment, manufacturers such as Boeing and Lockheed Martin Corp. build the wings and fuselages that make up the airframe. Meanwhile, companies such as General Electric and Pratt & Whitney manufacture the engines that propel aircraft. The third segment covers flight instrumentation, an area where the most profound advances in aviation have taken place. But the fourth segment, broadly defined by the industrial classification "aircraft parts not otherwise classified," includes manufacturers of surface control and cabin pressurization systems, landing gear, lighting, galley equipment, and general use products such as nuts and bolts.

Aircraft manufacturers rely on a broad base of suppliers to provide the thousands of subsystems and parts that make up their products. There are more than 4,000 suppliers contributing parts to the aerospace industry, including rubber companies, refrigerator makers, appliance manufacturers, and general electronics enterprises. This diversity is necessary because in most cases it is simply

uneconomical for an aircraft manufacturer to establish, for example, its own landing light operation. The internal demand for such a specialized product is insufficient to justify the creation of an independent manufacturing division.

There is a second aspect to this distribution tier, since aircraft manufacturers have found it cheaper and more efficient to purchase secondary products from other manufacturers, who may sell similar products to other aircraft companies, as well as automotive manufacturers, railroad signal makers, locomotive and ship builders, and a variety of other customers. For example, an airplane builder such as Boeing, Grumman, or Beech might purchase landing lights from a light bulb maker such as General Electric. Such subcontractors supply a surprisingly large portion of the entire aircraft. On the typical commercial aircraft, a lead manufacturer such as McDonnell Douglas may actually manufacture less than half of the aircraft, though it is responsible for designing and assembling the final product.

When a major manufacturer discontinues an aircraft design, as Lockheed did with its L-1011 Tristar, a ripple effect is caused that affects every manufacturer that supplied parts for that aircraft. Therefore, parts suppliers that make up the third tier of distribution strive to diversify their customer base to ensure the decline of one manufacturer will be tempered by continued sales to others. Given the unstable nature of the industry, parts manufacturers also attempt to find customers outside the aircraft business.

In terms of the distribution of helicopters to the end user, most units are produced only after an order has been placed for the vehicle. This is common for large assets that are intended for very specific purposes and therefore often require some level of customization.

KEY USERS

For many practical applications, helicopters are indispensable. They are used to perform important services for cities, industry, and government. Rescue missions and operations depend on the versatility of the helicopter for disaster relief efforts at sea and on land. The Coast Guard uses them regularly, and the ability of the helicopter to hover allows for harnesses to be extended to victims on the ground or at sea, who can then be transported to safety. Helicopters are also useful when rescuing lost or injured hikers or skiers. Hospitals now have helipads so accident victims can be transported as quickly as possible for emergency treatment. Police use them for aerial observation, tracking fleeing criminals, searching for escaped prisoners, or patrolling borders. Police and news agencies use the helicopter to watch for traffic problems in major cities.

Wildlife and forestry employees need helicopters for aerial surveys of animal populations and to track animal movements. Forestry personnel use the helicopter to observe the condition of tree stands and to fight fires. Helicopters transport personnel and equipment to base camps, and spray fires. The agricultural industry engages helicopters to spray fields and to check on and round up cattle.

Helicopters are especially useful to industry, performing jobs that require strength and maneuverability, such as hoisting heavy building materials to the upper levels of a high-rise and hauling awkward or large objects. They have also been used to erect hydro towers and other tall structures. Petroleum industries rely on the helicopter to observe pipelines for damage and to transport personnel to offshore drilling operations.

Helicopters are the prestige vehicle of choice when businesses want to impress clients and employees. Though expensive, helicopter flight is a convenient way to beat the traffic, and downtown businesses in large cities will often have heliports on top of their buildings. Helicopters transport passengers from the airports and are enjoyed recreationally by sightseers and hunters willing to pay for quick transportation to exotic locales.

While helicopters have improved greatly since the first piloted rotary machines of 1907, they are significantly slower than airplanes and cannot reach the same altitudes. Expensive and difficult to fly, helicopters are also highly versatile and can move in ways impossible for fixed-wing craft. This maneuverability makes the helicopter an essential tool for industrial, civil, and military service.

Helicopters in widest use in the U.S. armed services are the Sikorsky UH-60 Black Hawk and the Boeing AH-64 Apache. The Black Hawk, in service since 1978, is designed as a troop carrier and logistical support aircraft, but it can be used for medical evacuation, command and control, search and rescue, armed escort, and electronic warfare missions. The Black Hawk can carry 16 laser-guided Hellfire antitank missiles and a total weapons payload of up to 10,000 pounds of missiles, rockets, cannons, and electronic countermeasures. The helicopter can also transport up to 11 fully equipped soldiers.

Like its predecessor the Black Hawk, the Apache attack helicopter can carry up to 16 missiles as well as 76 aerial rockets for use againt lightly armored vehicles, and other soft-skinned targets. The Apache also boasts state-of-the art sensors that can identify targets in all types of weather during the day or night. Both the Black Hawk and the Apache played critical roles in ground attack, troop support, and supply during the Gulf War of 1991 and the Iraq War of 2003. The flexibility and firepower provided by modern military helicopters make them an indispensable part of the U.S. military arsenal.

ADJACENT MARKETS

Even the simplest modern helicopter contains thousands of parts whose peak functioning is essential to a safe landing. Indeed, a significant part of a helicopter's control panel contains instruments indicating whether the other instruments are working correctly; it is not as though, when something goes wrong, the pilot can pull over to the nearest cloud. The categories considered in this section include instrumentation systems and engine instruments. Products produced by these industry sectors are necessary to getting a helicopter off the ground, keeping it in the air, and touching down gently.

Guidance and Control Instrumentation. The products of this industry relevant to this essay include radar systems, navigation systems; flight and navigation sensors, transmitters, and displays; gyroscopes; and airframe equipment instruments.

The main suppliers of search and navigation equipment are the same contractors who supply the larger U.S. aerospace and defense industries, to which search and navigation equipment contribute significantly. Although not necessarily the most prolific producers of search and navigation instruments, many of the largest and most recognizable corporations in the United States have been involved in the business, including AT&T, Boeing, General Electric, General Motors, and IBM.

A substantial majority of the industry's product types fall into the avionics (aviation electronics) classification, which includes aeronautic radar systems, and air traffic control systems.

Historically, the primary customer for industry products has been the U.S. government—in particular, the Department of Defense and the Federal Aviation Administration.

Search and detection systems and navigation and guidance systems and equipment ($29.1 billion worth of shipments in 2001) constitute 91 percent of the total search and navigation market and include the following product groups: light reconnaissance and surveillance systems; identification-friend-or-foe equipment; radar systems and equipment; sonar search, detection, tracking, and communications equipment; specialized command and control data processing and display equipment; electronic warfare systems and equipment; and navigation systems and equipment, including navigational aids.

During the 1970s development of the Global Positioning System (GPS) satellite network began. Inertial navigators using digital computers became common devices in civil and military aircraft. Industry shipment values for the above products totaled $31.9 billion in 2001, an increase over the $29.9 billion shipped in 2000. Employment in the aircraft components sector in the United States also saw growth in the early 2000s. In 2001 the industry's employment base of 153,710 workers was nearly 12,000 people greater than the previous year. Capital investment, which totaled approximately $1 billion in 2000, had remained relatively constant since 1997.

Aircraft Engine Instruments. The main customers of the aircraft engine instruments segment are General Electric, United Technologies, Rolls Royce, and other aircraft manufacturers. This sector produces temperature, pressure, vacuum, fuel and oil flow-rate sensors, and other measuring devices. Growth in this market is linked to aircraft production.

Through the first decade of the twenty-first century, the miscellaneous measuring and controlling devices industry was projected to grow at an annual rate of 3 percent. Aircraft engine instruments were predicted to be one of the industry's faster growing segments. Furthermore, the addition of software and services will contribute to overall industry growth, as will further expansion into overseas markets. The top five export markets in the late 1990s were Canada, Mexico, Japan, United Kingdom, and Germany; these five countries also were the top import countries. Looking into the 2000s, estimates indicated 33 percent of measuring and controlling instrument product shipments would be exported, while 25 percent of U.S. demand would be met by imports.

RESEARCH & DEVELOPMENT

In a sector as competitive as the helicopter industry, it is easy to focus on matters of day-to-day survival. That has never been truer than in the early twenty-first century, when operators have been desperate for aircraft and manufacturers have been under pressure to meet rising demand and demanding production schedules.

What will airframes, power systems, and avionics look like over the next 40 years? That is a more complex question than it would first appear, since even with computer-assisted drawing equipment and high demand, it can take 10 years for a new helicopter to move from the drawing board to the field. Much potential remains for revolutionary advances in the science of vertical flight. Some industry experts feel helicopter technology hasn't advanced significantly since the 1970s; the basic air vehicle performance has remained largely unchanged since the end of U.S. military involvement in Vietnam.

Regardless of how individuals may feel about the need for war, many rotorcraft developments evolve to meet the requirements of the U.S. military. Combat operations in Iraq and Afghanistan, combined with the prospect that they will persist for some time and be coupled with operations elsewhere in the world, confront military and industry leaders with a simple fact: the Pentagon needs

an aircraft that can get off the ground and land without requiring a runway but can perform like a fixed-wing airplane in between.

The Bell Helicopter/Boeing V-22 can do that, and was scheduled to go into use in Iraq in 2006, but that process began in the late 1980s. To achieve greater speed, range, and payload, the experts cited the promise of a compound-helicopter design, using an auxiliary propulsion system to supplement the thrust of the rotors for greater forward speed. Fixed wings can provide extra lift. The Piasecki Aircraft, which has long worked on the concept of compound-helicopter design, is preparing its X-49A SpeedHawk for flight tests in 2007.

The Heliplane being developed with funding from the U.S. Defense Advanced Research Projects Agency (DARPA) uses a similar approach. The Salt Lake City-based autogiro maker Groen Brothers Aviation is designing a proof-of-concept, long-range, vertical takeoff and landing aircraft. DARPA's objective is to achieve performance with a rotary-wing aircraft comparable to that of a fixed-wing one.

The Smart Hybrid Active Rotor Control System (SHARCS) integrates actively controlled rotor blades to reduce helicopter noise and vibration. Performance tests of the 6.5-ft rotor were scheduled for early 2007, followed by wind tunnel tests in Milan, Italy. SHARCS is led by the Rotorcraft Research Group at Carleton University in Ottawa, Canada, with funding from the Canadian Natural Sciences and Research Council, AgustaWestland, Manufacturing and Materials Ontario, and Sensor Technology, Ltd.

Developing a low-drag hub alone would be a significant efficiency gain for tomorrow's rotorcraft. Experts said the vertical drag of a rotorcraft's hub is roughly equivalent to the entire drag of a fixed-wing aircraft of a similar gross weight, which greatly limits the performance of helicopters.

Tail rotors are another necessary evil on single main-rotor helicopters. They are critical to controlling torque and directional control, but they also add drag, increase the cost and complexity of maintenance, and generate a lot of noise. Most importantly, tail rotors are a safety weakness. They are a critical flight control that is susceptible to a single-point failure. In the late 1990s, developers and operators of unmanned air vehicles (UAVs) realized they were losing aircraft to single-point flight-control failures. They revised their designs to make them doubly, and lately, triply redundant. As a result, it is difficult to lose a UAV to a flight control failure.

Tomorrow's aircraft also are likely to be less expensive to operate. Since military operators are shifting life-cycle costs to aircraft suppliers through long-term support contracts, suppliers are motivated to maximize aircraft reliability. The United Kingdom has led in this contracting area, but the United States is expanding its use of this practice.

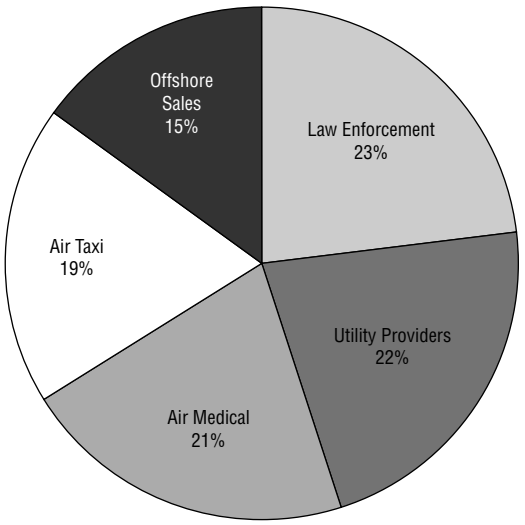
CURRENT TRENDS

Manufacturing processes and techniques will continue to change in response to the need to reduce costs and the introduction of new materials. Automation may further improve quality (and lower labor costs). Computers will become more important in improving designs, implementing design changes, and reducing the amount of paperwork created, used, and stored for each helicopter built. Also, industrial robots that can wind filament, wrap tape, and place fiber will permit fuselage structures to be made of fewer, more integrated pieces. Advanced, high-strength thermoplastic resins promise greater impact resistance and repairability than current materials such as epoxy and polyimide. Metallic composites such as aluminum reinforced with boron fiber or magnesium reinforced with silicon carbide particles also promise higher strength-to-weight ratios for critical components such as transmission cases while retaining the heat resistant advantage of metal over organic materials.

FIGURE 109

U.S. Turbine Helicopter Sales by Category of End User, 2000–2005

Market shares are shown based on average sales by end users category over the period 2000 through 2005.



SOURCE: Compiled by the staff with data from *Helicopter Market Newsletter Turbine,* Helicopter Association International. 2006.

TARGET MARKETS & SEGMENTATION

Helicopters have proven themselves so crucial to so many markets, they would seem to almost sell themselves. In truth there is a great deal of competition among helicopter manufacturers and each must maintain a close relationship with a large variety of institutional buyers.

The major target markets for helicopters are the agencies and organizations that use helicopters as a part of their very function. They include the military, law enforcement, tourism, firefighting, agriculture, construction, the wealthy, and hospitals. Because of the unique functionality offered by the helicopter, it has a built in audience and thus, a capitive market. Even the hazards inherent in all aircraft, particularly acute with helicopters since they often fly at relatively low altitude, with little time to react to a sudden event, do not deter from the popularity of this most useful machine. Air shows remain the most widely attended venues for customers old and new to marvel at the latest advances in aircraft design. Other ways in which helicopters are promoted include through the listings of helicopter charter companies in telephone directories and the plethora of Internet Web sites devoted to the sale, maintenance, supply and repair of helicopters.

RELATED ASSOCIATIONS & ORGANIZATIONS

American Helicopter Society, http://www.vtol.org

Competition Helicopter Association, http://torchs.org/clubs/clubs.htm

Helicopter Club of Great Britain, http://www.hcgb.co.uk

Helicopter Foundation International, http://www.hfi.rotor.com

Naval Helicopter Association, http://www.navalhelicopterassn.org

Popular Rotorcraft Association, http://www.pra.org

Rotor Rats, http://torchs.org/clubs/clubs.htm

Twirly Birds, http://www.twirlybirds.org

Whirly-Girls International, http://www.whirlygirls.org

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