Early pilots looked out of their open cockpits for roads, rail lines, and airports to find their way in daytime flight. Pilots watched the horizon to make sure they were flying with the aircraft's nose and wings in the proper position relative to the ground, called attitude. As airmail pilots began flying at night and in all kinds of weather in the early 1920s, new equipment helped pilots navigate and maintain aircraft attitude when they could not see the ground. Navigation aids were developed for use inside the aircraft and also to guide the pilots from the ground.

Simple equipment to help pilots maintain attitude was introduced during the 1920s. These devices included such ideas as a bubble of liquid to help keep wings level and a device that measured pressure at different heights, called an altimeter, that told a pilot his altitude above ground level. A simple magnetic compass for direction was installed either in the cockpit panel or held in the pilot's hand.

In 1929, Lawrence Sperry and his Gyroscope Company introduced important new technology—the Artificial Horizon—that operated on gyroscopic principles. With its sensitive attachments, Sperry's device could detect forces that upset the gyroscope's stable spin, then would activate the aircraft controls to maintain proper attitude while flying when visible flight was not possible.

In the 1930s, new mechanical aids emerged, some based on Sperry's gyroscope and others based on the rush of air through intakes under the wing or the aircraft belly to measure speed and altitude. Equipment outside the aircraft measured the velocity of the air as it entered one intake and exited another. The results were fed to the pilot to help him determine the aircraft's attitude and position.

Navigation information was displayed on a group of instruments called the basic or primary six, which included the attitude indicator, a vertical speed indicator showing the rate of climb and descent, airspeed indicator, turn-and-bank coordinator, a heading indicator showing the magnetic compass course, and the altimeter. These instruments are still used.

Refined versions of Sperry's invention appear in 2001 as the Inertial Navigation System (INS) and the Inertial Guidance System (IGS). These systems measure changes in the aircraft's location and attitude that have taken place since the aircraft left the ground. These new devices include an accelerometer to detect changes in airspeed as well as attitude. By determining the precise latitude and longitude before flight, then tracking every change in location, the INS or IGS tells the pilot where he has flown.

Radio navigation aids were developed around the same time as mechanical aids. In 1926, successful two-way radio air-to-ground communication began, and the first transmitter/receiver went into mass production in 1928. Teletype machines were installed so that all stations along an air route could transmit weather conditions to the pilot. Eventually the pilot used these stations to indicate the plane's location.

The earliest radio navigation aid was the four-course radio range, which began in 1929. Four towers set in a square transmitted the letters A and N in Morse code. A pilot flying along one of the four beams toward the square would hear only an A or N in the dashes and dots of the code. The dashes and dots grew louder or more faint as he flew, depending if he was flying toward or away from one of the corners. Turning right or left, he would soon hear a different letter being transmitted, telling him which quadrant he had entered.

The beams flared out, so that at certain points they overlapped. Where the A or N signals meshed, the Morse code dashes and dots sounded a steady hum, painting an audio roadway for the pilot. At least 90 such stations were in place by 1933, about 200 miles (322 kilometers) apart along the 18,000-mile (28,968-kilometer) system of lighted towers and rotating beacons. Unfortunately, mountains, mineral deposits, railroad tracks, and even the atmospheric disturbance of the setting sun could distort the signals.
In 1930, Cleveland Municipal Airport established a radio-equipped airport control tower. In the next five years, about 520 cities followed Cleveland’s lead. Controller Bill Darby is shown with the latest equipment in this 1936 view of Newark tower.

In 1930, Cleveland Municipal Airport established a radio-equipped airport control tower. In the next five years, about 520 cities followed Cleveland’s lead. Controller Bill Darby is shown with the latest equipment in this 1936 view of Newark tower.

The first radio-equipped airport control tower was built in Cleveland, Ohio, in 1930, with a range of 15 miles (24 kilometers). By 1935, about 20 more towers had been erected. Based on pilot radio reports, a controller would follow each plane with written notes on a position map. The controller would clear an aircraft for takeoff or landing, but the pilot still could decide on the best path for himself.

Until World War II, radio navigation relied on low frequencies similar to those of an AM radio. Devices such as the automatic direction finder and the non-directional beacon, like the 1920s system before them, used Morse code, and the detection of weaker to stronger volume let a pilot know if he was on course. After the war, higher frequency transmitters, called the very high frequency omni-directional radio range or VOR, further refined the early concept of allowing pilots to fly inbound or outbound along a certain quadrant on a line called a radial. These transmitter locations, their frequencies and identifying Morse codes are all printed on navigation charts. The various radio-based systems are sufficient for navigating between airports but are called non-precision aids because they are not accurate enough and do not provide enough information to allow a pilot to land.

Before World War II, the Civil Aeronautics Administration relied on pilots to radio their position relative to known navigation landmarks to keep the aircraft safely separated. During the war, radio detection and ranging (RADAR) was tested. Radar’s primary intent was, and still is, to keep airplanes separated, not to guide them to a specific point.

In 1956, a TWA Lockheed Super Constellation with 64 passengers and six crew and a United Airlines DC-7 with 53 passengers and five crew collided over the Grand Canyon, killing all 128 people. The incident led to new federal funding for rapid development of radar, air traffic control procedures, and technologies for more precise navigation. The crash also led to an aviation agency reorganization that included creation of the Federal Aviation Agency.

Today's aircraft are tracked as computer-generated icons wandering across radar display screens, with their positions, altitude, and airspeed updated every few seconds. Pilots and controllers communicate using both voice and data transmitting radios, with controllers relying on radar tracking to keep aircraft on course. Today, cockpit navigation information is increasingly displayed on a monitor, but the position of information and its format are nearly identical to the basic six instruments of early and simpler aircraft.

New technologies, though, have led to a debate as to whether the federal government, using fixed electronic stations, or the pilots should control navigation like in the earliest days. The global positioning system (GPS) is one technology that allows pilots to accurately determine their position anywhere on the Earth within seconds, raising the question whether they need any help from the ground.

GPS is becoming the primary means of navigation worldwide. The system is based on satellites in a continuous grid surrounding the Earth, each equipped with an atomic clock set to Greenwich, England, called ZULU time. The GPS units in the aircraft, or even in a pilot’s hand, find the nearest two satellite signals in a process called acquisition. The time it takes for the signals to travel creates a precise triangle between the two satellites and the aircraft, telling the pilot his latitude and longitude to within one meter or a little more than one yard. In coming years, this system will be made even more precise using a GPS ground unit at runway ends.

Despite these advances, pilots can still crash because they get lost or lose track of hazards at night or in bad weather. On December 29, 1970, the Occupational Safety and Health Act came into effect. It requires most civilian aircraft to carry an emergency locater transmitter (ELT). The ELT becomes active when a pilot tunes to an emergency radio frequency or activates automatically when the aircraft exceeds a certain force in landing, called the g-force, during a crash. This form of navigation aid, which transmits signals to satellites overhead, saves lives of injured pilots and crew who are unable to call for help themselves.

--Roger Mola

Selected Bibliography and Further Reading


http://www.centennialofflight.gov/essay/Evolution_of_Technology/nav...


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