It was only 86 years ago that Orville and Wilbur Wright made the first successful powered flight on Kill Devil Hill near Kitty Hawk, NC. However, last year marked the 50th anniversary of another major but lesser known milestone in flight and electronics engineering which has contributed significantly to the growth, development and safety of aviation as we know it today. This historic event occurred in 1939 at Indianapolis Airport, Indiana when the first operational VHF/UHF Instrument Landing System (ILS) was installed to provide air derived guidance data.

Four years later, in 1943, United States government civil and military representatives met at the Pittsburgh Airport in Pennsylvania and made the decision to standardize the VHF/UHF Instrument Landing System. In 1946 the International Civil Aviation Organization (ICAO) also recognized the need to standardize approach and landing systems and selected the U.S. VHF/UHF Instrument Landing System as the new international standard. This system became officially effective in 1950 through the provisions of Annex 10 to the Convention on International Civil Aviation.

During the past fifty years, the number of U.S. federally owned and operated VHF/UHF ILS systems has grown steadily to more than 940 systems in the United States and its territories today. Concurrent with the growth of the Federal ILS systems has been a continuously increasing demand for non-Federal ILS systems which are sponsored and operated by states, municipalities and counties as well as private companies and individuals. Each of these non-Federal ILS systems must be approved by the Federal Aviation Administration (FAA) before being placed in service and all are FAA flight and ground inspected at regular intervals. It is important to point out that these non-Federal ILS systems do provide a vital service that otherwise would not be available for hundreds of communities throughout the country. Many of these non-Federal systems will become or are now eligible for FAA assumption of ownership or maintenance.

With this background in mind, the following sections are intended to provide the reader with an insight of the evolution of ILS equipment and the role of the Civil Aeronautics and Federal Aviation Administrations in their development.

**ILS LOCALIZER**

In 1938, Andrew Alford invented a VHF loop antenna which produced pure horizontally polarized waves. The resultant radiation pattern in the horizontal plane of the loop is circular. Since about 1943, the basic localizer array utilized eight Alford loops (one carrier pair and three sideband pairs) arranged to provide a front course down the runway centerline and a reciprocal "back-course" of essentially the same radiation characteristics as the "front-course."

The first parabolic localizer antenna was experimentally tested at Indianapolis and Minneapolis. Both of these installations provided straight courses for evaluation. However, the localizers were plagued with low clearances and false courses on either side of the main course projected down the center of the runway. A few years later it was suggested that a five-loop clearance array could be used to mask out false courses and provide full scale clearances. "Capture effect" principles were employed by placing the parabolic array and the clearance array on two frequencies separated by 8 KHz.

In 1951, the first full-scale highly directive antenna system using a slitted waveguide was constructed of galvanized sheet-iron material. After testing several apertures, the final waveguide was 117 feet long, 77 inches wide and 40.75 inches
high. The waveguide was comprised of 18 probe-fed slots, the center of which was approximately 52 inches above ground. An 8-loop array was employed to mask out the side-lobes and false courses of the waveguide which occurred on either side of the main beam. The 8-loop array also produced back-course and false courses of the waveguide which occurred on either side of the main beam. The 8-loop array also produced back-course in addition to providing left or right full scale indications of the localizer indicator in the off-course areas.

The first directional waveguide array was commissioned at Meacham Field, Fort Worth, TX in 1957. A total of 28 waveguide facilities were commissioned in the United States between 1957 and July 1965.

In June 1962, Scanwell Laboratories developed a VHF directional localizer array. The antenna array had a wide aperture, consisting of 15 V-ring elements and had a directional pattern comparable to the waveguide antenna array. A separate clearance array was not required. The V-ring antenna consisted of a ring-driven element and a V-shaped reflector.

The first localizer was commissioned at Washington, D.C. in 1941. By July 1, 1965, the FAA had installed 210 8-loop, 28 waveguide and 9 V-ring localizers throughout the United States.

Back in the days of vacuum tubes, the earlier localizer systems required several tall racks of electrical equipment and large mechanical motor-alternators to generate the 90 Hz and 150 Hz navigation tones. The transmitters incorporated high power modulators for station identification and voice modulation. AC power consumption was in the order of several thousand watts. The antenna array was a small aperture (about 35 ft.) and essentially omni-directional with Alford loops used as the radiating elements.

The RF carrier power needed to provide the required usable distance of 25 miles, varied from 150 to 175 watts. Accordingly, this high level of RF signal radiated in all directions presented a major concern for adjacent channel frequency protection.

The modern localizer antenna systems utilize uni-directional traveling wave or uni-directional log-periodic dipole elements. Bi-directional V-Ring elements are used at facilities where a localizer back-course is required. The number of elements (thus the aperture of the array) is tailored to the electromagnetic environment encountered at a selected site. A 14-element wide aperture array (over 100 feet) can be energized to provide a course beam width in the order of 5 degrees. In view of the fact that the minimum usable distance has been reduced from 25 miles to 18 miles and the use of highly directive antenna arrays, the RF carrier power requirement is now typically 15 watts or less. It is therefore significant to note that this large reduction of RF carrier power in conjunction with sharp beam-widths reduces adjacent channel frequency protection requirements.

**ILS GLIDE SLOPE (IMAGE-ARRAYS)**

The glide slope has presented siting problems which are more difficult than those pertaining to the localizer. This is due to the extremely narrow, low-angle vertical beams required for the antenna patterns.

At 330 MHz it is very difficult at the small vertical angles involved to provide an array with sufficient vertical directivity (i.e., wide enough aperture) to be unaffected by ground reflec-
ILS GLIDE SLOPE (NON-IMAGE ARRAYS)

In the early 1950s, various configurations of a non-image end-fire glide slope antenna array employing Yagi antennas were designed at the CAA Technical Development Center. Experimental tests were conducted at the Greenville Airport, SC.

By the late 1950s, R.H. McFarland of Ohio University designed waveguide trough antenna elements that were embedded in the runway and flush with the surface of the runway. This end-fire system was partially successful, but was abandoned mainly for insufficient horizontal coverage and installation/maintenance problems.

Development efforts for an end-fire glide slope antenna system were resumed in the early 1970s by Chester Watts. The newly designed end-fire array employed slotted cable antenna elements to provide the required azimuth coverage and used capture effect techniques to provide off-path clearance signals. The first end-fire glide slope system was commissioned at the Rock Springs airport in 1978. More than a dozen Federal and non-Federal end-fire glide slope systems have since been commissioned. U.S. Patent No. 3,699,582 entitled “Slotted Cable Glide Slope Antenna” was issued to Chester Watts in October 1972.

In the early 1970s, Westinghouse successfully modified the Airborne Instrument Laboratories (AIL) and developed waveguide glide slope to provide Category II performance. This broadside (non-image) array is still in operation at some problem sites.

Accordingly, non-image glide slope systems utilize either a slotted waveguide antenna or an end-fire configured array of slotted cable elements.

ILS MARKER BEACON

The earlier ILS marker beacon antenna array consisted of two half wave co-phased, collinear dipole antenna elements spaced above a 20-foot counterpoise. The counterpoise was elevated 6 feet above ground level to permit reliable operation under snow conditions. The antenna elements were spaced 40 inches (approximately 3/8 wavelength) above the counterpoise. A separate antenna mounted on the edge of the counterpoise serves to monitor the radiated signal. The relatively large vacuum tube transmitters were housed in a building that also contained the low frequency NDB transmitter which is no longer required.

The first permanent 75 MHz ILS marker beacons were installed by the CAA in about 1939. By November 1965, there were approximately 246 outer markers and 243 middle markers installed in the United States.

The modern solid-state marker beacon transmitters are enclosed in a weatherproof cabinet and at some sites are pole-mounted. Single or dual Yagi antenna arrays that employ integral monitoring are supported on a pole that elevates the array 19 feet above the ground level. There are more than 1600 marker beacons in service at the present time.

RELIABILITY

Today’s modern equipment requires less than 12 cubic feet of space with an almost unbelievable reduction of A.C. power consumption.

Typical power consumption for a localizer or a glide slope is less than 300 watts and less than a 100 watts for a marker beacon. More importantly, the use of solid-state electronics has greatly increased system mean-time between failures to more than 8,200 hours for localizer equipment, to more than 11,000 hours for glide slope equipment and to more than 61,400 hours for marker beacon equipment.

AVIONICS

Over the years there has also been some remarkable improvements in the design and performance of aircraft ILS receivers. The earlier vacuum tube receivers were large, heavy units that were rack mounted with remote displays and in some cases used long, flexible shaft tuning controls (often referred to by the old timers as “coffee grinders”). Modern solid-state ILS localizer receivers incorporate digital frequency synthesizers for tuning and some units are so small that they are part of the panel-mounted cross pointer display. On high performance aircraft, the familiar “steer-horn” ILS antenna has been replaced with flush-mounted or radome protected antenna elements.

As mentioned earlier, the ILS provides air derived navigation guidance data, i.e., the original guidance data is produced in the aircraft and is directly available to the pilot and/or the autopilot without retransmission from the ground. This was a paramount consideration in the development of an approach and landing guidance system for civil operation. It should be noted that the military Ground Controlled Approach (GCA) system provided ground-derived guidance information which was voice-transmitted by the radar operator to the pilot of the approaching aircraft. Although GCA for various reasons is desirable for certain military operations, it has been unacceptable for normal operation in the civil sector.

CONCLUSIONS

With the various glide slope systems and the highly directional localizer antenna arrays in FAA inventory, successful ILS performance can now be achieved under the most adverse electro-magnetic environmental conditions.

When considering the fact that an approach to a landing is the most critical phase of any flight, it is well worth noting that there has never been an aircraft accident attributed to faulty ILS signals. This outstanding performance of the VHF/UHF Instrument Landing System is well recognized throughout the aviation community and will remain the primary precision landing system in the United States through the year 2000.

The Microwave Landing System (MLS), Global Positioning Satellites (GPS) or some system not widely known, or as yet developed, may eventually replace the ILS. Whenever this happens, the VHF/UHF Instrument Landing System will have successfully served the aviation community for more than half a century of safe and effective airport approach and landing service.

In light of modern ILS capabilities, it is unfortunate that Wilbur and Orville are not here today to make a precision ILS approach in a modern jet aircraft under Category III weather conditions.