TUBES, TRANSISTORS AND TAKEOVERS

From Bakelite to back courses and from Boonton to Phoenix: How the Aircraft Radio Corporation changed aviation.

BY GORDON ELIOT WHITE

The marvels of modern general aviation avionics have piled so rapidly one upon another that we view as routine our ability to communicate and navigate electronically while airborne. It was not always thus, and the development of reliable electronics has taken 75 years of uneven progress.

Aircraft Radio Corporation, of Boonton, New Jersey, is one of the companies that helped pioneer aviation radio. Late last year, Cessna sold ARC to the Sperry Corporation, and Sperry is assimilating the entire product line into its Phoenix, Arizona, operation. This move brings to a close 57 years of avionics design and production at the old company's laboratory and plant in the rolling hills of northern New Jersey.

ARC began as a laboratory, developing products to be made of one of the earliest plastics. In the decade after World War I, as aviation moved from the country-fair stunt circuit to a position of commercial importance, the company began expanding to become a major innovator and designer of aircraft radio equipment.

As with engines and airframes, aviation communications can trace its origins to the military; in this country, the specific time was August 1910, when the Signal Corps made the first airplane-to-ground transmission. The Army realized the value of an aerial fleet that could be commanded from the ground, and two months later the first plans for development of such defense were discussed at the International Aviation Tournament at Belmont Park, Long Island.

The first airborne communications were in Morse code. By 1917, voice was being transmitted in the air, and World War I accelerated that development. In 1918, Western Electric Corporation's SCR 68 became the standard Allied aircraft radiotelephone.

Military work languished in the aftermath of the First World War. Patent suits prohibited Army purchases of the new superheterodyne receivers. Barnstorming private pilots could not afford radio. So, as things stood then, any continuing development in the early 1920s was for commercial aviation.

Charles Lindbergh carried no radio in the *Spirit of St. Louis* 57 years ago, but he did have the Sperry-built earth-inductor compass, the first electronic aid to navigation. His flight so caught the imagination of the world that it generated a rush of efforts to make flying safer and more reliable. One enthusiast was mining magnate Daniel Guggenheim, who set up the Guggenheim Fund for the Promotion of Aeronautics, offering a cash prize for the first successful blind landing.

The federal Bureau of Air Commerce, created in 1934 to help promote aviation, laid out the first airways marked by strings of light beacons on tall towers between major cities. The BAC followed that with a plan to set up radio beacons for pilots to follow.

Jimmy Doolittle won the Guggenheim blind-landing prize in 1929 using a receiver designed by Radio Frequency Laboratories.

The ferment in the aviation field attracted a number of new firms, one of which was the Seabury Company, established in 1912 to produce items made of a new plastic material called Bakelite, invented by Dr. Bakeland. Bakelite has excellent insulating properties and still is used in household electrical fixtures. In 1927, Seabury set up a subsidiary in Boonton to exploit the use of Bakelite in radio equipment.

The new company, known as Radio Frequency Laboratories, hired Edward Weston, Stuart Ballantine and Lewis M. Hull, among others, to develop circuits to be farmed out and produced by manufacturers under contract or license. The ensuing inventions included basic automatic volume control and several amplifier circuits.

Within two years, RFL became known well enough that a young U.S. Air Corps lieutenant and MIT graduate by the name of James Harold Doolittle asked the company to build a receiver to be used to win the Guggenheim blind-landing prize. RFL developed a receiver that picked up the signals that Doolittle used to drive a vibrating reed instrument on his panel; this device told him whether he was right or left of his course. Doolittle won the prize at Mitchell Field, Long Island, in 1929—the same year that RFL's non-aviation patents were sold in the consolidation that created the RCA Corporation.

RFL improved that early version of its receiver and offered it to the airline companies as the Model B, covering the frequencies used by the BAC route beacon signals. The Model B, which used a tuned radiofrequency amplifier,

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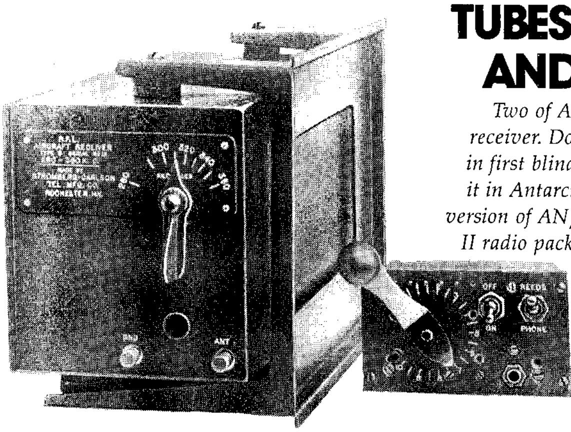
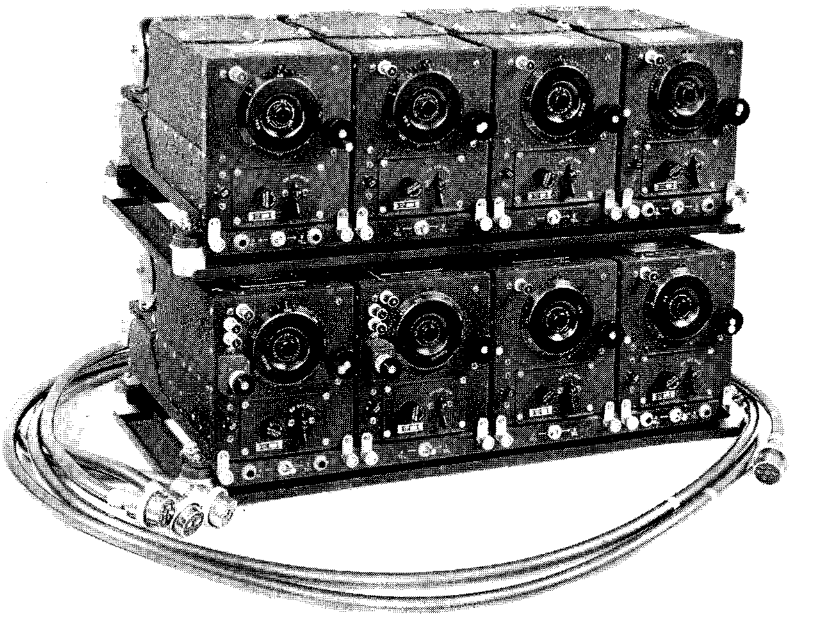




Two of ARC's finest. Left, Model B receiver. Doolittle used an early version in first blind landing. Richard Byrd used it in Antarctic flight. Below, preliminary version of AN/ARC-5, ubiquitous World War II radio package for U.S. military aircraft.

was subsequently produced as the SCR-183. It became the standard military radio of the early 1930s. The transmitter portion of the -183 was designed for short-range "command" work messages from the leader of a flight to the rest of his formation. It did not have much power and suffered from frequency drift due to vibration and variations of temperature, pressure and power supply voltage in the open-cockpit military airplanes.

Commercial aviation was not restricted by the patent fight over the superheterodynes. The airlines were able to afford the cost, space and weight of the best radio equipment money could buy, much of it built by Western Electric. In contrast, the military was living hand-to-mouth, and private pilots were either wealthy enough to buy airline equipment or too poor to buy anything at all.

In 1934, while still dependent upon the short-range SCR-183 (the U.S. Navy version was known as RU/GF), the Army was ordered by President Franklin D. Roosevelt to fly the airmail; the commercial contracts had been cancelled because of alleged corruption. Taking over nationwide routes in the depth of February on only 10 days' notice, an unprepared Aviation Section tried valiantly to carry out the order, in its open-cockpit Boeing P-12s. Within a month, 10 pilots were dead, and the nation realized just how woefully unprepared the Air Corps was, in view of a potential air war. Inadequate radio and navigation equipment was one of the major factors in the debacle.

The resulting investigation by a board headed by former Secretary of War Newton B. Baker set in motion a complete overhaul of American military aviation. Among the Baker board's fruits was the establishment of requirements for far better radio and navigation equipment.

RFL, by then renamed Aircraft Radio Corporation, played a significant role in the new developments. By 1934, ARC had its own landing field in the Rockaway Valley of northern New Jersey, with a white-painted wooden hangar and laboratories amid bucolic woodland surroundings. The company bought its own airplane, a Berliner parasol monoplane, for developmental work, and hired a retired Army pilot, Russell (Luff) Meredith. ARC's relations with the Army's best pilots were friendly—officers would fly from Washington to Boonton for a weekend in Chief Engineer Fred Drake's home. After an afternoon of hunting, they would sit with drinks in front of the big fieldstone fireplace for an evening of hangar flying and talk about air strategy, tactics and radios.

The army fliers were so friendly with ARC that they finagled one contract for Drake—a contract on which Western Electric actually underbid him—by having Western Electric declared not a "responsible bidder."

In 1935, Drake began designing a new series of military aircraft radios. They were to meet his ideas of the equipment the Army needed, setting new standards of stability and reliability, and were to contain multiple channels. The Model B and the SCR-183 had used a rack full of plug-in coils to change frequency bands. Their dials were marked from 0 to 100, and to tune in a particular frequency, the pilot had to refer to a calibration chart. The new equipment would be marked directly in kilocycles or in megacycles.

Drake's design, which used superheterodyne techniques, consisted of miniaturized receivers half the size of the SCR-183. The designers brilliantly solved stability problems by developing a temperature-compensated tuning circuit. The mathematical basis of "tracking" the local oscillator and the incoming signal over the tuned band was worked out by engineer Paul O. Farnham so that the shape of the mechanical capacitor provided the offset required. Various components in the receivers were designed as easily replaceable items, before either of the terms "miniaturized" and "modular" was coined.

These so-called "channel" sets were first built in the ARC laboratories in 1935. Known as Type K within the company, they were far in advance of other equipment then available, but they did not meet the letter of official Army requirements.

Development continued at Boonton

for three years before the Navy finally ordered a prototype Type K system; the Navy adopted the design as its GT/RBD set in 1940. However, the Army Signal Corps was engaged in a conflict with the Air Corps over aircraft radio specifications and insisted on developing a crystal-controlled set. Bendix Radio, a long-time builder of air carrier equipment, developed the set the Signal Corps wanted, the SCR-240—but it was the size of a footlocker, and the airmen rejected it.

In May 1940, Roosevelt called for a 50,000-airplane air force to meet the threat of war in Europe. The Army asked Bendix to copy the GT/RBD, but in August 1940, it abandoned that effort and adopted the ARC set in toto as SCR-274-N. The N stood for "Navy," the only time the Army would so designate an aircraft radio item as having originated with its sister service.

Anyone who flew during World War II can recall the SCR-274-N, the various Navy versions, and the final joint-nomenclature set, AN/ARC-5. These were ubiquitous in military aircraft, and the low-frequency range receiver, R-23 (BC-453) remained in service until recently, particularly in aircraft that flew overseas where Adcock ranges are still used.

Western Electric, Colonial Radio and Stromberg-Carlson helped ARC produce nearly 1.4 million receivers, transmitters, modulators and other individual items of the basic system, known generically as the "command sets."

Crystal control, though accepted in commercial flying, was rejected early in World War II because of the critical shortage of radio-grade quartz. Eventually, sufficient crystals did become available, and multichannel crystal-controlled equipment was designed. British development of VHF radio was another wartime advance, and UHF units were developed for the AN/ARC-5 system.

During the crystal-tunable debate, ARC designed a technically elegant, tunable VHF receiver and a less satisfactory non-crystal transmitter, in the Type K modules. In 1945, the Civil Aeronautics Administration used the receiver section as the basis for its first VHF omnirange receiver.

Western Electric, Bendix, General Electric and RCA had built commercial radio equipment before the war, along with Wilcox, Sperry, Harvey-Wells, Northern Radio and others. Little of it, however, was adapted to private aircraft except some fairly simple GE and RCA designs.

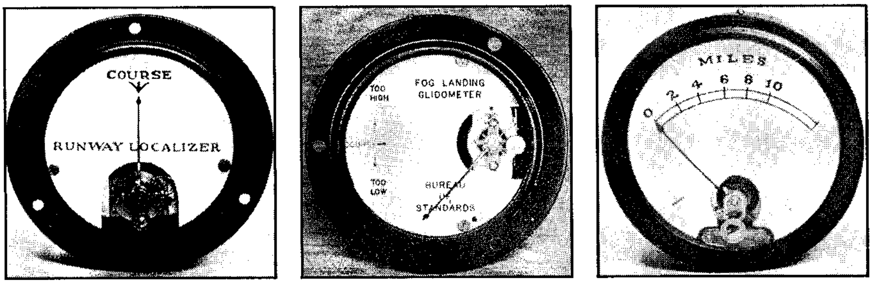
Because ARC's President Lewis Hull had rejected the Army's and the Navy's vast expansion plans of 1940, at the end of World War II the company was neither saddled with an enormous plant to convert to peacetime work nor faced with an apparent demand that it seek new markets. ARC planned to continue doing what it had done brilliantly in the late 1930s—design and produce small quantities of top-quality, state-of-the-art aircraft radio equipment.

Immediately after the war, ARC engineers worked with the Civil Aeronautics Administration developing a receiving system to operate with the new omnirange navigation system. The receiver was an update of the 1944 R-112/ARC-5 unit, with the frequency coverage adjusted slightly. ARC very quickly converted the beacon and broadcast band SCR-274N and AN/ARC-5 receivers into civilian models with little more than a different paint color (gray) and a lighter and simpler rack and joint system.

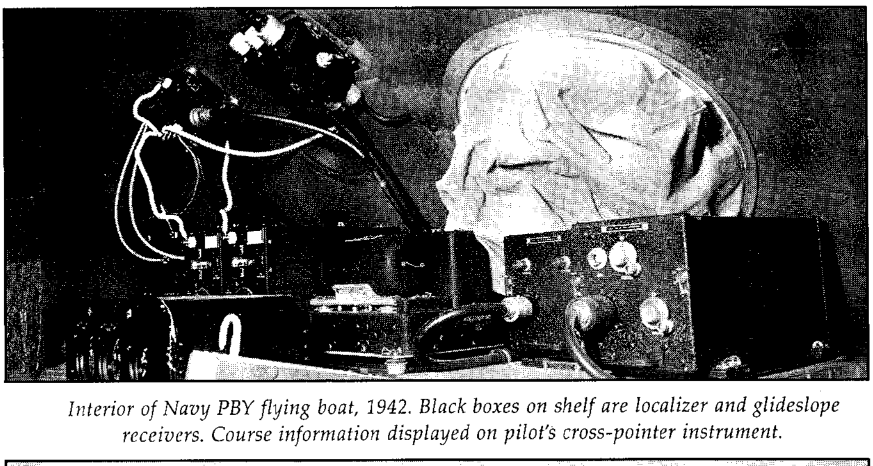
The wartime transmitters in the HF bands were only briefly produced as civilian items—too many thousands of surplus units were already on the market—but ARC designed a small, much more compact VHF transmitter that worked with the updated receivers.

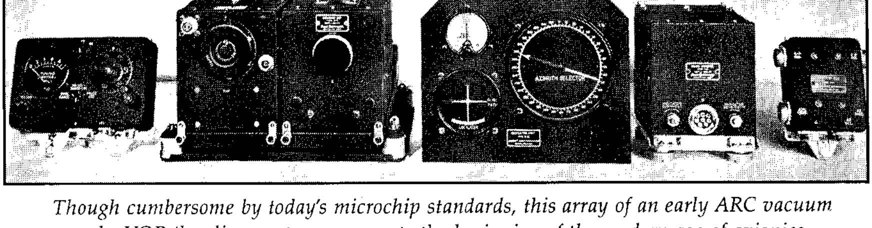
ARC's former military market, however, never again materialized, and Bendix and Collins Radio took the airline sales. Business aircraft constituted the market that ARC needed, but when the brief postwar private aircraft bubble collapsed in 1947, ARC lost money for the first time in a dozen years.

The Korean War, which began in 1950, rescued the people up in Rockaway Valley. The Army began to create its own air force of small twin-engine and single-engine airplanes and helicopters for which the ARC equipment was ideal; even if based on a 1936 de-



Early equivalents of course deviation indicator, glideslope and distance measuring equipment.


Interior of Navy PBY flying boat, 1942. Black boxes on shelf are localizer and glideslope receivers. Course information displayed on pilot's cross-pointer instrument.


Though cumbersome by today's microchip standards, this array of an early ARC vacuum tube VOR/localizer system represents the beginning of the modern age of avionics.

sign, the equipment was nicely updated and still quite reliable.

Some oddball units came out of Korea, including a "transverter" that converted VHF signals in the 118-148-MHz band into the 220-MHz frequency area of the Air Force AN/ARC-27 transceiver. Since the ARC-27 and its sister equipment were designed for B-47 bombers and heavy Air Force fighters and could not be accommodated in helicopters, ARC threw together the transverter, known as AN/ARC-60, to enable them to use an existing low-band VHF system.

The company went into electronic test equipment and autopilots, course directors and other expensive navigation gear aimed at the military. Nevertheless, when the Korean War ended, ARC once again faced economic difficulties. Lacking the size and reserves of larger companies, it could not amortize the cost of its research or production facilities over enough sets to remain competitive. Its prices were so high that the General Accounting Office was called into audit costs on at least one government contract.

By the 1950s a number of ARC engineers who had done much of the World War II work were leaving to set up their own companies or join others—Stuart Ballantine and Atherton Noyes were prime examples, but there were a dozen others—and ARC was closer to hanging on the ropes.

ARC worked with Laurence and David Rockefeller's Airborne Instruments Laboratory on Long Island, developing a classified airborne radar countermeasures set. The Rockefellers bought up a controlling interest in ARC and sought to merge the company into an electronics conglomerate, reminiscent of the way RCA had been formed 20 years earlier with RFL's patents.

A flirtation with Litton Industries left some former ARC stockholders wealthy and others frozen out.

Finally, in 1959 Hull negotiated a stock swap that made ARC a wholly owned subsidiary of Cessna Aircraft. Cessna was seeking an in-house source of radio equipment for its general aviation aircraft, a type of equipment built to meet a price, that was unlike the designs the old hands at Rockaway Valley had built. (Predictably, discontent, grumbling and rifts affected the staff.)

At that time, the transistor was poised to push the vacuum tube out of

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aircraft electronics, the most revolutionary change in technology since Lee de Forest invented the vacuum triode.

The equipment ARC built to Cessna's requirements bore no relationship to the World War II sets. It did not measure up to the cost-is-no-consideration military designs. Transistors provided smaller transmitters and receivers but not necessarily better performance. Engineers who were at ARC at the time say that the rotary switches were cheaper, the crystals were cheaper, the designs were cheaper.

Within the company the older hands carried on with military work, but a number of ARC bids on later government projects failed to yield any business, because ARC costs were out of line or because ARC could not afford the old ploy of "buying in" on a contract cheaply and then making its profit on follow-ons or cost overruns.

There were attempts at other work under Cessna. Hydraulic experts from Wichita proposed a line of systems to automate farm equipment such as tractors, and backhoes, but a cash shortage killed the project.

Paul B. King Jr. engineered the first successful frequency synthesizer, following classified work by H.F. Hastings and Robert Stone at the Naval Research Laboratory, but secrecy restraints prevented ARC from commercially exploiting King's breakthrough before others had reached the market. (A frequency synthesizer allows the combining of highly accurate signals from a few crystals to be combined and recombined to generate an almost unlimited number of channels—this permits the building of a 360-channel transceiver, since using 360 separate crystals would be prohibitively expensive and bulky.)

Under Cessna, ARC designed a few military systems that were as well-built as ever, though none of them became as important as the World War-II sets. There were the AN/ARC-39, a prototype Air Force liaison set; the Type 210 VHF transceiver, a subminiature ADF for Coast Guard helicopters; and the ARN-30D, a beautiful little 190-channel omni receiver in a package that still fit the old AN/ARC-5 racks.

It was the end of the line for the command sets and the end of the line for ARC. The design, several times updated, had survived for nearly 30 years, but the reputation it had made for ARC finally was obliterated.

By the end of the 1970s, death and retirement had taken virtually all of the original engineers. When the aircraft depression of the 1980s struck Cessna, ARC was expendable: in December 1983, Cessna sold the line to Sperry.

The laboratories of Boonton have been closed, and the equipment and fixtures auctioned. The production line was still running in April but all work there is scheduled to cease by the end of the year. Manufacture of some of the remaining ARC line is to be shifted to Sperry's Phoenix facility. □

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AVIONICS FROM THE ATTIC

The ARC "attic" is rich in relics and artifacts from the earliest days of aircraft radio development. A recent discovery, among the rafters high in an old ARC hangar, was a mast antenna believed to be the first vertical aircraft antenna, devised by Luff Meredith.

The contents of that attic, well-known to avionics historians, are being donated by Sperry and Cessna to the Smithsonian's Air and Space Museum and to the New Jersey Aviation Museum at Teterboro. The Smithsonian's collection will include a Model B beacon receiver much like the one used in an airplane flown by Lieutenant James Doolittle at Mitchell Field in 1929.

The Air and Space Museum acquired, in 1983, the author's collection of more than 2,600 items of ARC and command-set hardware, plus 755 drawings, photographs, notebooks, manuals and other documentation on the equipment. The collection also includes many design models, prototypes and one-of-a-kind versions of the command sets.

According to museum director Walter J. Boyne, the Smithsonian has plans to set up a display of World War-II avionics in 1985 and to create a comprehensive avionics exhibit for its proposed facility at Dulles International Airport, when the new building is completed in approximately six years. —GEW