TM 11-660

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

INTRODUCTION TO ELECTRONICS

DEPARTMENT OF THE ARMY • JULY 1949

DEPARTMENT OF THE ARMY TECHNICAL MANUAL
TM 11-660

INTRODUCTION TO ELECTRONICS

DEPARTMENT OF THE ARMY JULY 1949

United States Government Printing Office
Washington: 1949

DEPARTMENT OF THE ARMY

WASHINGTON 25, D. C., *13 July, 1949*

TM 11-660, Introduction to Electronics, is published for the information and guidance of all concerned.

[AG 300.7 (4 Feb 49)]

BY ORDER OF THE SECRETARY OF THE ARMY:

OMAR N. BRADLEY
Chief of Staff, United States Army

OFFICIAL:

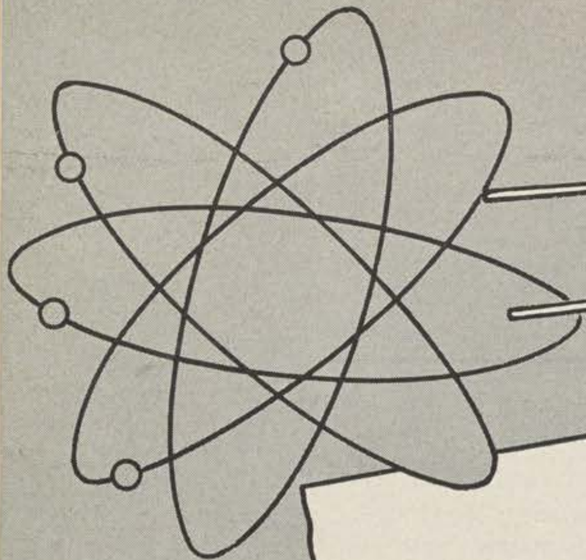
EDWARD F. WITSELL
Major General
The Adjutant General

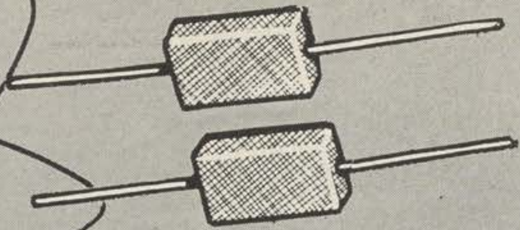
DISTRIBUTION:

Tech Sv (2); Arm & Sv Bd (1); AFF Bd (ea Sv Test Sec) (1); AFF (5); OS Maj Comd (5); Base Comd (3); MDW (5); A (ZI) (20), (Overseas) (5); CHQ (2); D (2); (B) 1; R (1); Bn (1); FC (2); USMA (2); Sch (5); PMS&T (1); Dep (2) except Sig Sec, Gen Dep (10), Dep 11 (5) except Baltimore & Sacramento (20); Lab 11 (2); PE (10); OSD (2); 4th & 5th Ech Maint Shops 11 (2); T/O & E 11-7 (2); 11-15 (2); 11-47 (2); 11-57 (2); 11-87S (2); 11-95 (2); 11-107 (2); 11-127 (2); 11-537T (2); 11-547 (2); 11-592 (2); 11-597 (2); 11-617 (2); SPECIAL DISTRIBUTION.

For explanation of distribution formula see SR 310-90-1.

CONTENTS





Introduction

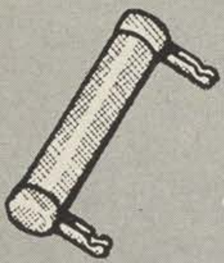
THIS IS A STORY of the electron—an ingredient of all matter in the universe—a particle so tiny that its presence is not detected by the world's most powerful microscope—and yet whose motion constitutes the basis for the marvels of electronics.

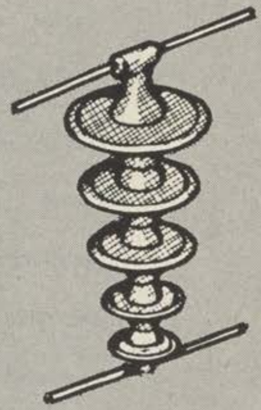
This is also a story of the men of electronics at whose bidding—as if with magic wands—wondrous feats of incomparable wizardry are performed.

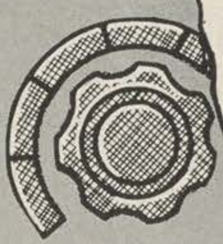
Nor are these opening words about magic and wizardry too fanciful.

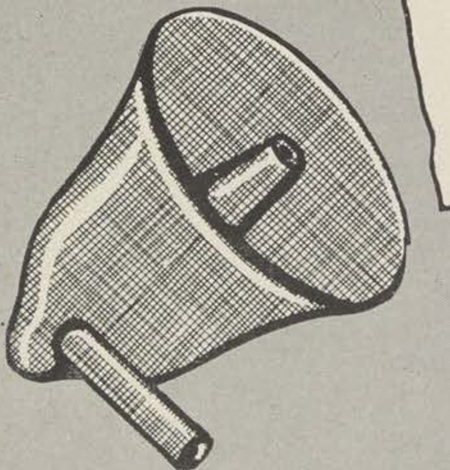
Electronic devices—under the control of skilled fingers—accomplish feats more incredulous than any related in the Arabian Nights and in all other stories dreamed by ancients.

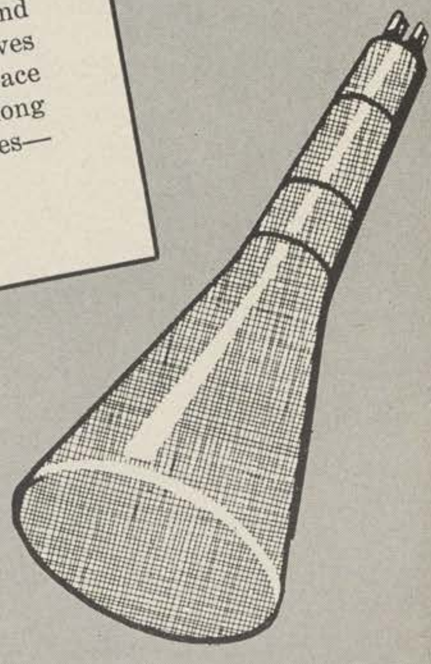
This is a preview of electronics and its generators of electromagnetic waves which—after being catapulted into space—travel with the velocity of light along the roadways of the sky. These waves—

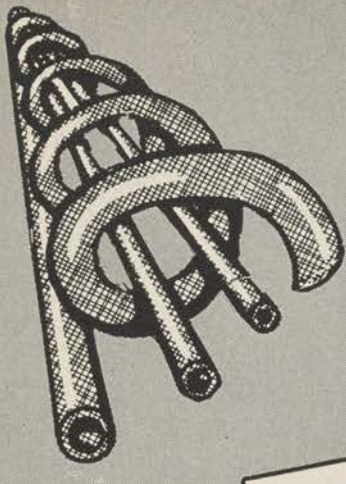


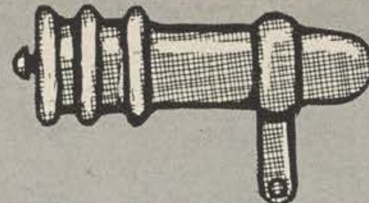


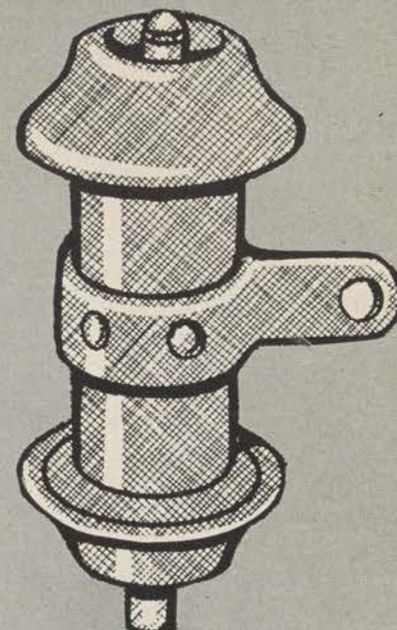








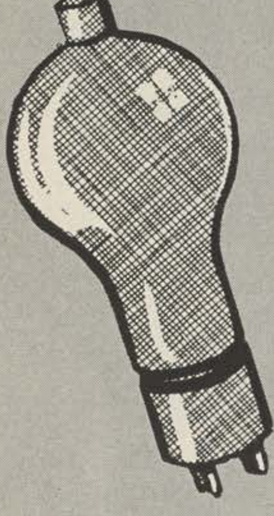


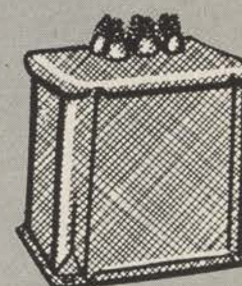


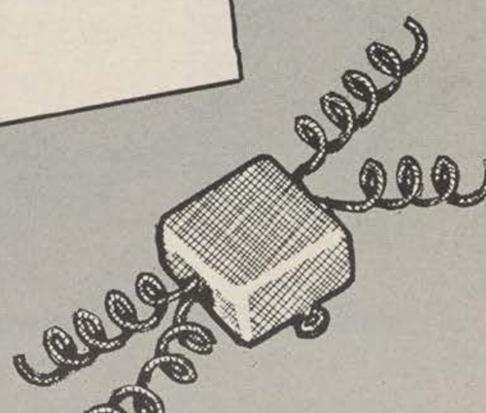
the "magic carpets" of the electronic world—serve as phantom conveyors for many kinds of intelligence. Sounds originating in Cairo, Shanghai, Johannesburg and other distant points on the globe are heard in Chicago or Miami—events happening in Washington are viewed in Brooklyn—objects hidden from the eye by darkness and fog are unerringly detected and located—positions at any spot on earth are found—weather conditions are quite accurately prophesied—the height of an aircraft above the earth or the depth of a submarine below the surface of the ocean is determined—screaming projectiles are accurately aimed at targets beyond the optical horizon. Through its magic, even Mr. Moon is contacted.

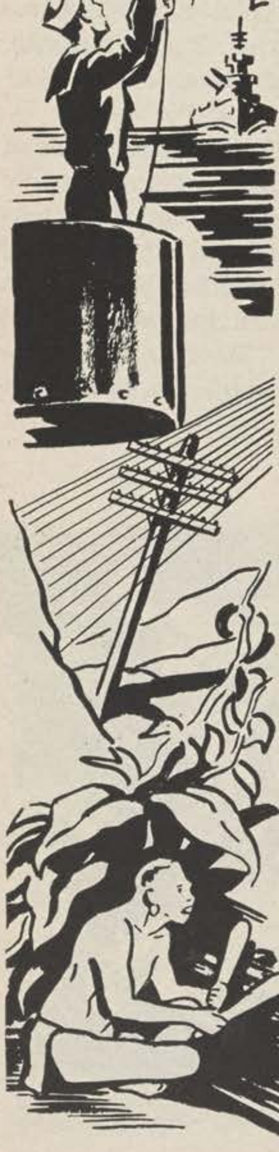
And yet these successes do not conclude the story, because electronics is still in its "twenties"—scarcely a score of years of age.

To some, this book is an introduction. It is an introduction to the pursuit of those paths which lead to the command of Electricity, Radio, Radar, Television, Telegraphy, Telephony—to the command of the "March of the Electron."







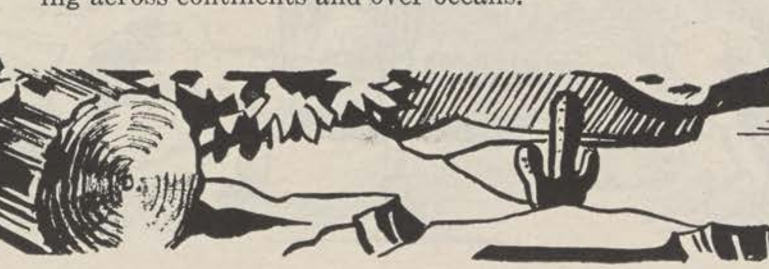


Section One

EVOLUTION OF COMMUNICATIONS

Since the dawn of civilization, man has been striving almost constantly to extend the distance over which he could communicate with his fellowmen. Yet, until the middle of the nineteenth century, direct communications were still limited to the use, over audible and visible ranges, of signaling devices such as drums, torches, smoke, and flags.

During the nineteenth century, however, discoveries in electricity opened the way for the inventions of the telegraph and telephone which, in turn, laid the basis for further development in communications and heralded the coming of an entirely new science, that of electronics. Under the impetus of this new science, man has developed almost unbelievable systems of distant communications and has discovered the media for speaking across continents and over oceans.



Bells, Horns, Drums, and Muskets

Perhaps the oldest method of distant communications was the relay of information from point to point by means of the spoken word or "shout." For secret transmissions, the voice was often disguised in order to withhold information from all except those for whom it was intended. Stories of frontier days tell of Indians imitating the sounds of animals and birds of the forest as they signaled their own parties in codes which they hoped would be unintelligible to our early frontiersmen.

But as the need for extending the distance that could be obtained by voice signals became apparent, a variety of sound devices came into widespread use. Bells, horns, drums, muskets, and cannon, among others, were used to send signals over distances. Likewise, a variety of "codes" were developed in order to make these sounds portray intelligence.

Even today, African Congo tribes make use of so-called "talking drums" as a basic means of communications. The drums are actually hollow logs so designed that five different tones can be obtained during the manipulations of an expert drummer. With the intonations of the drums closely approximating the five tones of the native language, a rhythm is produced which carries much the same meaning as if spoken words and phrases were uttered and amplified. For distant communications, a number of drummers are stationed along a route with the tones of the original drummer being relayed, in turn, by each of the other drummers. Thus, as the jungle reverberates to the five tones of the "talking drums," messages are sent across its breadth to all persons of the Congo within range of the intonations.

Torches and Lanterns

Communication by means of light signals is another of man's basic means of transmitting messages.

Some two thousand years ago, the Greeks employed a simple light signaling system for the transmission of important news between neighboring cities. In their system, a code enabled each letter of the Greek alphabet to be represented by the display of a certain number of torch lights to the right and left of a fixed central position. The Greeks used as many as ten torches to represent certain letters.

Ancient mariners devised light codes for the purpose of carrying on communications between ships on the high seas, and historic old lighthouses employed light beams to guide ships at sea, either warning them of perilous waters or guiding them to a safe moorage.

At the outbreak of the Revolution, a pair of lanterns hung in the belfry of Old North Church in Boston was the signal which informed Paul Revere of the coming of the redcoats by sea. The prearranged code was simply: "One (light) if by land and two (lights) if by sea."

Since that time the "speed and silence of light" has been used repeatedly for signaling purposes.

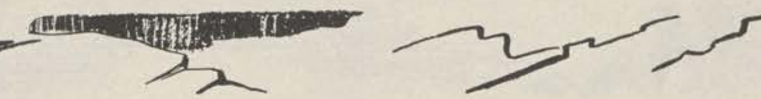
Even today, light signals are still used for special purposes, although the torch and the lantern have been replaced generally by the electric light.

Smoke and Flags

Smoke and flags are two other signaling systems which depend on the sensitivity of the human eye for detection. Daytime signaling by these means has often been used.

During our campaign against hostile Navajo Indians in 1860, Major Albert J. Myer, the first Chief Signal Officer in the U. S. Army, made successful use of flag signals. In his code, called the Myer Code, only one flag is used for the transmission of any message. It is interesting to note that the Navajos, during this same campaign, made extensive use of smoke signals.

Along with the development of light and other visual signaling systems, a variety of accessories were developed to increase the range and efficiency of operation. Among these accessories are telescopes, binoculars, flares, rockets, balloons, and kites.



Section Two

WIRE TELEGRAPHY

In 1837, an American named Samuel Morse exhibited a rather strange looking contraption called the electric telegraph, a device which would probably be described today as a sort of "Rube Goldberg" fantasy. But to the people of that era, the results accomplished by his contraption were awesome, even mystifying.

For did not this telegraph enable a person to communicate with his friend at distances beyond the range of human vision?

Did not the communication take place almost instantly?

Was not the "electric fluid" which made his device operative a truly magic substance?

Yes, the electric telegraph completely captured the imagination of these folks; and justly so,

because the telegraph was the first instrument ever invented by means of which the distance barrier to communications could be hurdled. Indeed, Morse had harnessed Ben Franklin's electricity and had driven it over wires in such a manner that signals could be conveyed in the form of dots and dashes—the well known Morse code.

Coast-to-Coast

A few years after the telegraph was first exhibited, a Congressionally financed telegraph line installed between Washington and Baltimore carried the first public telegraph message, those famous words "What hath God wrought?" From this time wire telegraphy progressed rapidly, and before the end of the Civil War great strides had been made. By 1875, coast-to-coast telegraph networks had been built by the Signal Corps for the singular purpose of gathering meteorological information. Shortly afterward, the function of the telegraph was extended to permit the handling of signals from lighthouses and life-saving stations along the coasts. Note that, at this early date, the primary peacetime uses were those of emergency control. Eventually, these Signal Corps telegraph networks were acquired, expanded, and developed more fully by commercial concerns.

Around the World

Even as our telegraph system was being extended, wire telegraphy was making strides in other countries. With the Atlantic Cable and other submarine cables a reality, telegrams were soon being relayed from country to country. Today, telegraph lines are installed in virtually every community of the world, and telegraph service is within the reach of practically all peoples for normal and emergency communications.

A Call to Arms

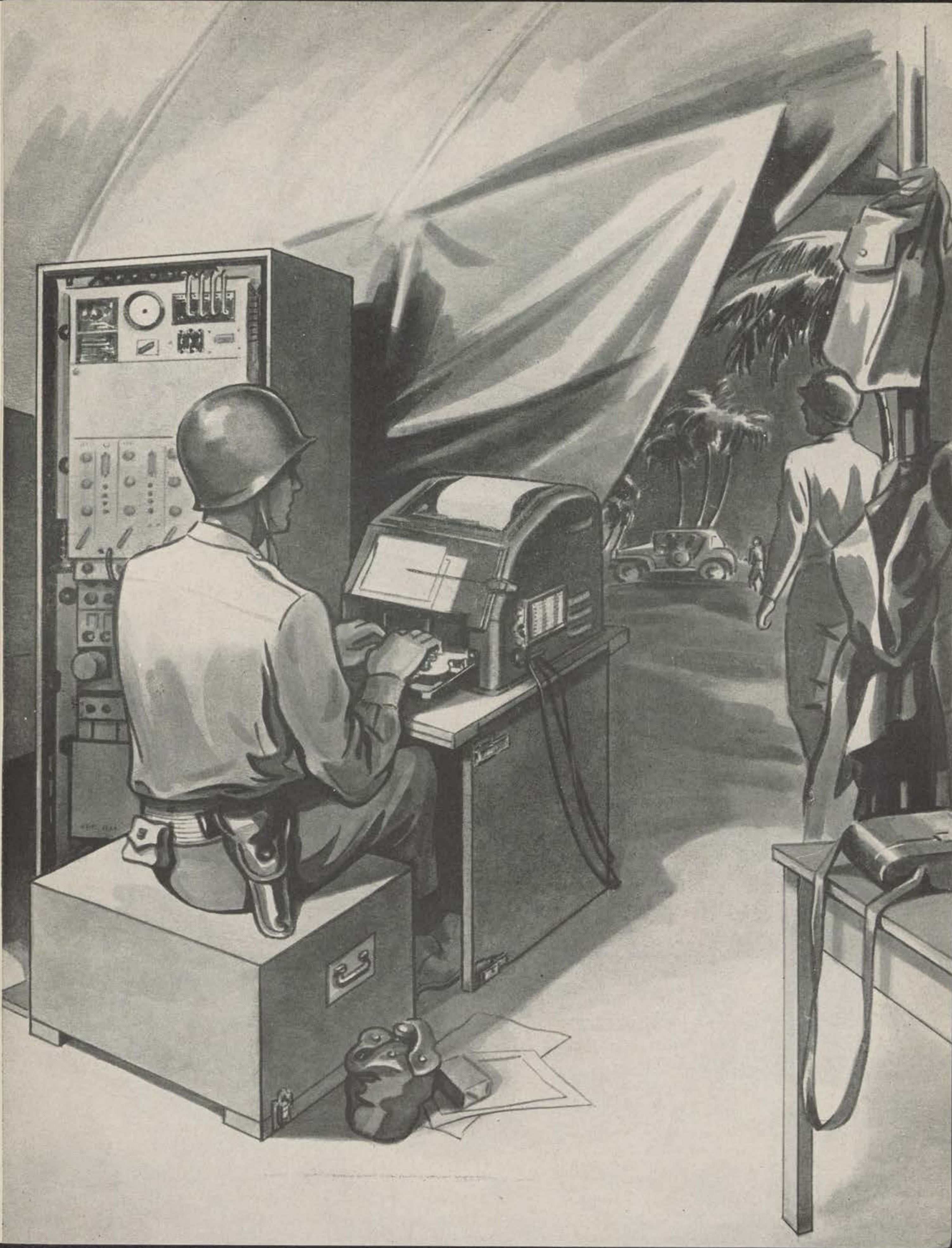
The importance of wire telegraphy to military communications can hardly be overemphasized. It is more reliable and exact than any other method of electrical signaling. A noted general of the United States Army paid a fitting tribute to the system of wire telegraphy and to the men who operate it when he stated: "As a means of tactical control, wire services in the hands of trained, skillful, and fearless men may be regarded as an indispensable adjunct of modern war."

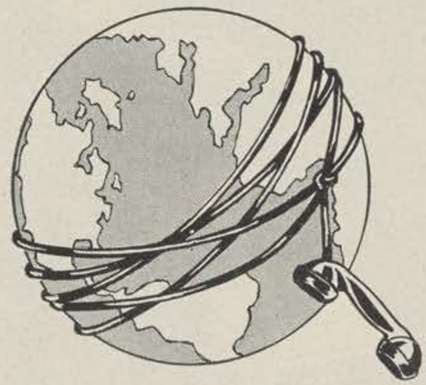
This indispensability is not a new conception. As far back as the Spanish-American War, the extreme importance of wire telegraphy was realized. In fact, at the very beginning of the campaign against Santiago, one of our ships sailed up under the fire of the Spanish batteries in Morro Castle to enable our men to grapple and cut the enemy's underwater telegraph cable. The successful completion of this operation disrupted the signal communications network of the Spanish.

With the Speed of Light

One of the marvels which lend to electrical communications a near magic quality is the speed at which the signal travels. Along copper wires, electrical energy travels at speeds approaching the velocity of light—186,000 miles per second. Such speed is sufficient to enable an electrical signal to travel around the world several times each second. For this reason, electrical communications are sometimes referred to as instantaneous communications.

TELEGRAPHERS IN THE COMMUNICATIONS CENTERS OF THE SIGNAL CORPS AND OTHER BRANCHES OF THE ARMED SERVICES TRANSMIT AND RECEIVE CODED MESSAGES BY MEANS OF THE TELETYPEWRITER. DURING TRANSMISSION, A SERIES OF ELECTRICAL IMPULSES IS SENT OUT OVER A WIRE LINE EACH TIME ONE OF THE TELETYPEWRITER KEYS IS TAPPED. THE TELETYPEWRITER ALSO RECEIVES THE INCOMING MESSAGE AND RECORDS IT AUTOMATICALLY IN TYPED FORM.





Section Three

TELEPHONY

After the invention of the telegraph, it was only natural that men should try to penetrate further into the incalculable regions of electrical communication. In fact, an entire pilgrimage in scientific pioneering set forth and many explorations in electrical research were undertaken. Some experimenters sought out a way to transmit the human voice over wires. Out of these efforts, that wonder of wonders, the talking telegraph, was hoisted into the realm of the marvelous-come-true.

In 1876, an American named Alexander Graham Bell exhibited his telephone at the Centennial Exposition in Philadelphia.

That the Deaf Might Hear

Bell spent his early life as a teacher of elocution, specializing in the instruction of the deaf by means of a system which he called visible speech.

In 1872, he opened a school of vocal physiology in Boston for the purpose of correcting stammering and for practical instruction in visible speech. It was here that he carried on research work to devise apparatus that might help deaf children—a machine to hear for them, a machine that would render visible to their eyes the vibrations of air that affect the ear as sound. The device, in itself, was a failure, but the apparatus, in the process of time, became the telephone of today.

The First Hookup

Bell's telephone was an ingenious application of Michael Faraday's discovery of electromagnetic induction in the early part of the nineteenth century. Bell utilized the principle of electromagnetic induction to convert the vibrations of air produced by a spoken word into electrical vibrations of current in the conducting wires. At the receiver, Bell reversed the process and converted the electrical vibrations of current into sound vibrations which could be heard by the listener.

The first words clearly heard over a telephone circuit were uttered by Bell himself. "Mr. Watson, come here. I want you." Watson, a friend of Bell, was listening through a receiving instrument located two floors away from Bell's transmitter.

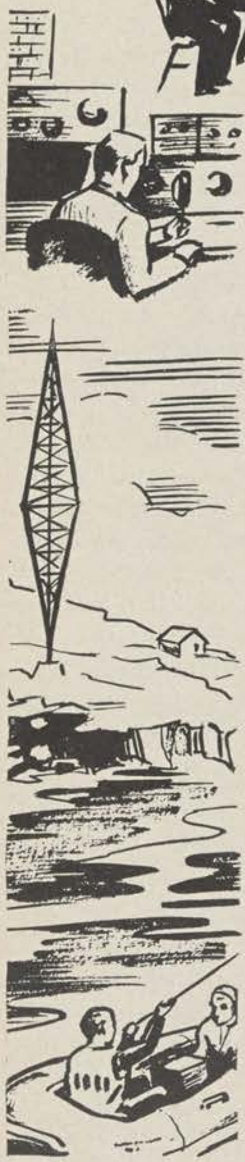
Spanning the Nation

From this humble beginning, telephony rapidly expanded as telephone lines were constructed and improvements made to extend the range over which the voice could be carried along the conducting wires. Constant developments were made in perfecting the transmitting and receiving instruments. Telephone exchanges were constructed to handle the ever-increasing number of telephone calls. In January, 1915, Bell again conversed over a telephone circuit with his old friend, Watson. At this time, however, Watson was in San Francisco while Bell was in New York City. Instead of two floors separating the transmitter and receiver, an entire continent lay between the two gentlemen. Telephonic service had spanned the nation.

Worldwide Networks

Today, the telephone industry is one of the largest in the world. Assisted by devices such as vacuum tubes and other electronic innovations, telephonic service has become highly efficient. A complex maze of wire networks extending above and below the surface of the earth and even under the sea is tangible proof of the success and common acceptance of this medium of communication.

TELEPHONE SWITCHBOARDS OF THE MILITARY SIGNALING SERVICES, MANNED BY CRACK OPERATORS, CONTROL A CONTINUOUS FLOW OF MESSAGES. THOUSANDS OF CALLS PASS THROUGH THESE SWITCHBOARDS WHICH FORM PART OF THE COMPLEX EQUIPMENT USED TO OBTAIN SPEEDY CONTINENTAL AND TRANSOCEANIC COMMUNICATIONS.



Section Four

RADIO

The story of radio is, first of all, the story of electromagnetic waves in space. It has been said that there has never been engendered in the human imagination a conception so incredible as that of these waves which travel through space at the speed of light, a speed which, by comparison, would make the fastest-flying jet-propelled airplane seem almost stationary.

The story of radio is also a portion of the story of electronics, a science which places within our grasp and obedient to our commands that tiniest particle of matter in the universe—the electron.

A Procession of Geniuses

Electrons and electromagnetic waves—under these two headings can be grouped the works of many of the men of radio—researchers and their researches, inventors and their inventions, experimenters and their experiments. For radio, as we know it today, is not the result of the idea of any single genius. Instead, the achievements of a score of men stand out with almost equal boldness—notable achievements which have given impetus and direction to the work of thousands of scientists, engineers, technicians, and others—achievements which, if taken collectively, would form a lengthy procession of scientific wonders.

Invisible Light

At the head of such a procession could well be placed the magnificent speculations of Michael Faraday concerning the relativity of all forms of energy, such as light, heat, electromagnetism, and gravity, or the renowned works of James Clerk Maxwell, who sought to prove the assumptions of Faraday by mathematical methods. Maxwell, extracting bits of evidence from his vast knowledge of science, actually predicted the existence of electromagnetic waves and, of all things, their exact speed of propagation, 186,000 miles per second.

Next in the procession could be placed the classical researches of Heinrich Hertz, which made the waves of Faraday's imagination and Maxwell's hypothesis things of definite and known quantity. Before completing his investigations, Hertz showed not only that electromagnetic waves were similar to light waves and were propagated at the same velocity, but also that these electromagnetic waves were actually "invisible light," or waves which vibrated at a rate so much lower than light waves that they made no impression on the eye. His experiments further proved that these waves could penetrate certain opaque substances such as wood and rubber in much the same manner that light waves pass through transparent materials such as glass or water.

A Wireless Machine

Yet these men, engrossed as they were with the more fundamental aspects of electromagnetic waves, probably never dreamed that their waves would someday be used to convey a multitude of globe-encircling dispatches—that their waves would someday be used to girdle the planet with words and music. It remained for other men at later dates to build the machines to make this possible. Guglielmo Marconi was one of these men.

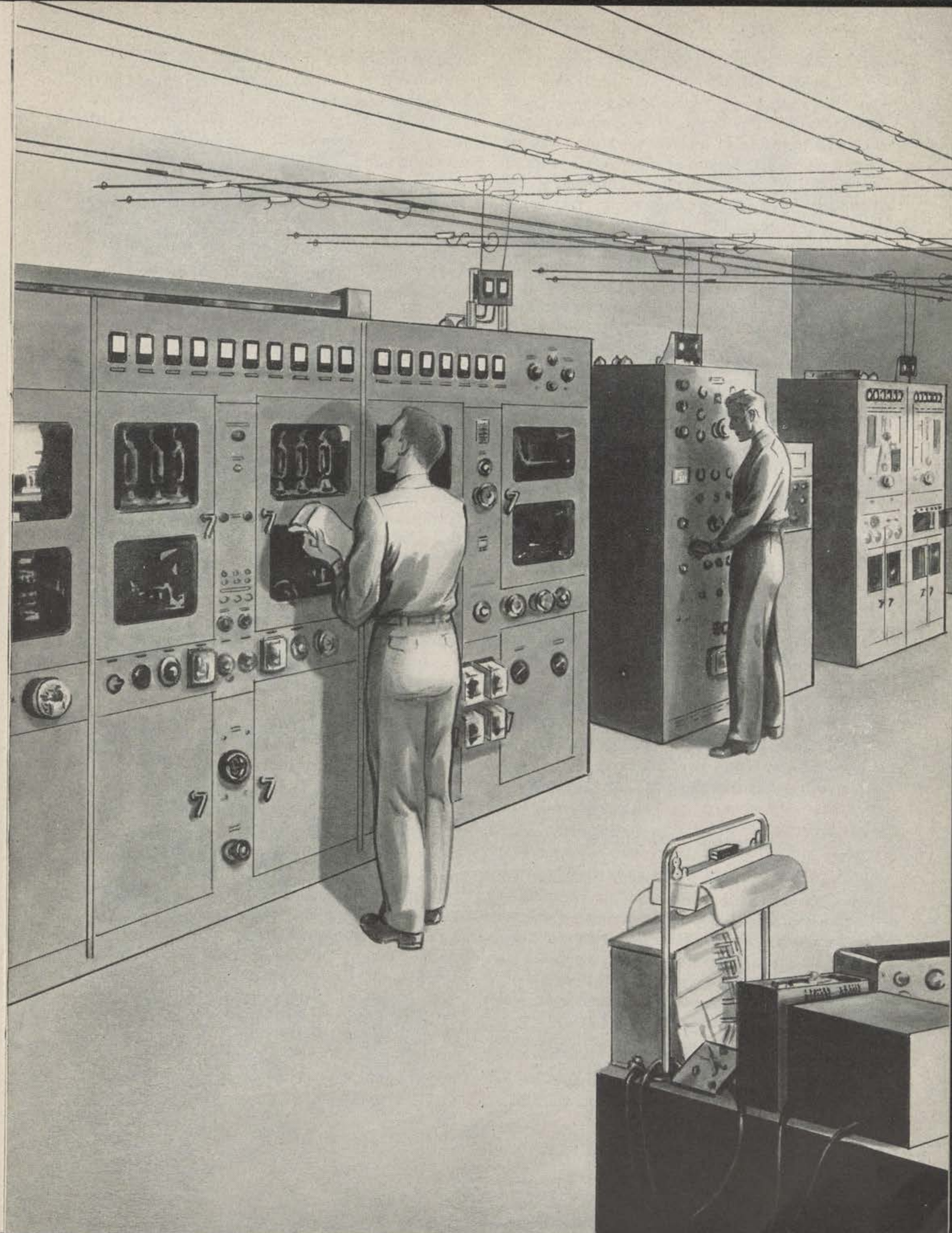
Young Marconi was completely fascinated with the thought of using these electromagnetic waves as a means of wireless communication. His historic experiments, occurring in rapid sequence, proved beyond all doubt that such communication was not only possible but also of potentially great practical value. In 1896, on the Salisbury Plains of Wilkshire, England, Marconi successfully used his transmitting machine to launch a signal into space—a signal which was picked up by his receiving apparatus located two miles away. Two miles—not far as judged by the travels of radio waves today but far enough to prove that wireless telegraphy was not just a scientific speculation—far enough to prove that a new horizon in communications had been reached.

This demonstration was only the beginning. In 1897, the same year that J. J. Thompson discovered the electron, Marconi was communicating by means of electromagnetic waves at distances of twenty-four miles. A year later, the range was extended to thirty miles. In 1899, regular wireless telegraph service was established across the English Channel. The dots and dashes of the telegraph had taken to the air. By 1901, Marconi's tall transmitting antenna at Poldhu, Wales, radiated three short bursts of high-frequency power which were detected by a receiver located at St. John's, Newfoundland. The wireless machine had sent a message across the Atlantic Ocean! And a clumsy and grotesque looking machine it was—yet a machine that worked, a machine that was to become the forerunner of today's mammoth generators of these magic waves.

An Aladdin's Lamp

Although wireless communication was on its way, many developments were necessary before the apparatus, transmitting staccato signals in the form of the dots and dashes of the Morse code, could be used for the propa-

FORTY-THOUSAND-WATT RADIO TRANSMITTERS PLAY AN IMPORTANT PART IN THE SCIENCE OF MILITARY SIGNALING. HIGHLY SKILLED SIGNAL CORPS TECHNICIANS PLAY THEIR PART TOO IN INSURING CONTINUOUS AND SUCCESSFUL PERFORMANCE OF THESE RADIO GIANTS.



gation of voice signals. Foremost among these developments was the electron tube, the modern Aladdin's lamp of science. This tube, a device used to control the flow of those tiny, negatively charged particles of matter, electrons, was the result of a succession of discoveries and inventions. This tube made possible new and practical methods of generating, rectifying, and amplifying high-frequency energy. In short, the tube revolutionized wireless communication. Other developments, further discoveries, and more inventions had to be made before an apparatus could be created for radiating programs through the ether—programs to inform, to instruct, to please, and sometimes to inspire listeners.

A Lot from a Little

Today, radio is a striking example of our ability to control the tiny electron and to launch electromagnetic waves into the great pool of space in our universe. Today, radio is a thing of strange proportions. Using a small amount of electrical energy, less than that consumed by the smallest electric bulb, the radio operator can radiate waves into space, waves which travel at the speed of light, to reach his listener who may be in any part of the world. Incredulous? Maybe so; yet it happens every day, thousands of times each day. Fascinating? To be sure; over 100,000 men and women pursue the hobby of amateur radio operation. Rewarding? It must be; countless numbers of men and women have found profitable vocations using the skills gained in the study of electronics.

On Ship and Shore

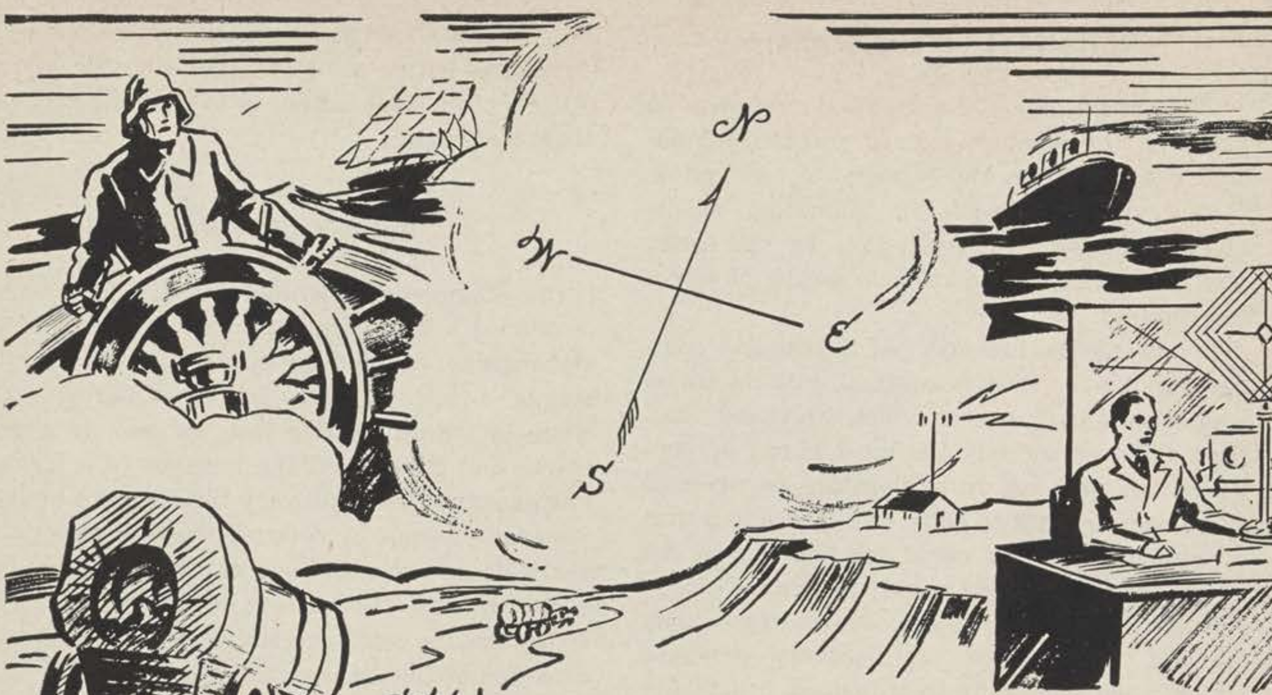
Since those early experiments of Marconi, wireless telegraphy—or as it is now called, radiotelegraphy—has been playing an ever-increasingly important part in communications. For the advent of voice-modulated waves did not supersede but only supplemented the signals of dots and dashes. Each new year finds more transmitters radiating the bursts of power which conform to the characters of the international Morse code. Today, radiotelegraphy is the chief method of long-range communications for thousands of ocean craft in their routine as well as emergency contacts with ship and shore stations. It is used by hundreds of commercial news-gathering agencies, by the military arms of the world's governments, and by scores of other organizations. Referred to now as CW, meaning continuous wave, it is almost a radio world of its own. Employing thousands of highly skilled operators, technicians, and engineers to make, install, service, and operate its complicated equipment, radiotelegraphy occupies a prominent place among industries.

At the Twist of a Dial

But the radio best known to most persons is the radio of words and music, radiotelephony. This phase of radio is of tremendous size and importance in the world in which we live. Through the vast coverage of radio, the farmer, the airline navigator, and the steamship captain are able to hear weather forecasts; important news dispatches are brought into practically every home; the songs of great artists, the selections of famous orchestras, the featured plays of the stage—all of these are obtainable at the twist of a dial. Radiotelephony is an integral part of our airways, our railroads, our police and fire departments, and scores of other services. Our army, navy, and air forces use this method of communication for a myriad of purposes.

A New Language

Radio technicians and operators can talk for days about the technical aspects of radio—about a new transmitter capable of generating a half-million watts of high-frequency energy—about the functioning of pulse circuits and microwave lines in a Signal Corps radio relay system—about a seemingly endless variety of electronic techniques. Their language—unintelligible to the uninitiated—is an inseparable part of their interesting world. In fact, the technical aspects of electronics and electromagnetic waves are so fascinating to those skilled in the art that many of these men spend much of their spare time and burn the midnight oil often without any material recompense. For proof, again witness the hundreds of thousands of radio amateurs and experimenters.



Section Five

RADIO DIRECTION FINDING

Before the invention of the magnetic compass and the radio direction finder, voyagers looked to the stars and other heavenly bodies in order to determine their direction of travel and their location on the surface of the globe. The positions of these heavenly bodies—placed as they are with divine exactitude—were used to determine the paths over which armies marched, the routes of pioneer merchantmen, and the courses set by helmsmen of ancient sailing craft.

Today, this method of navigation, called *celestial navigation,* is an exact science and a most accurate means of navigation. Yet, despite its inherent accuracy, there are reasons why it has been supplemented and sometimes replaced entirely by newer methods. For example, when dense clouds obscure the visibility of the sky, celestial navigation is useless.

North Needle Explorations

The invention of the magnetic compass is probably the most important single contribution ever made to the science of navigation. This instrument, with an indicating needle always seeking the North Pole of the earth, provides a simple and reliable means of direction finding.

Following the invention of a practical compass during the twelfth century, general travel was opened over routes which previously had been followed by only the most hardy of voyagers. A new era in exploration commenced as pioneers sought to learn of new trade routes over which caravans could roll and of new sea routes for the safe and speedy passage of sloops and other ships of the sea. Many expeditions set out on voyages of discovery—voyages which were eventually to transpass practically all the land and sea areas of the earth.

Yet the magnetic compass alone did not provide a complete solution to the problems of navigation because it indicates only direction. For location- or position-finding knowledge, celestial navigation and the use of known landmarks were the only available methods until the development of radio and its application to direction- and position-finding service.

Directional Reception

In the early days of radio, experimenters noted that electromagnetic waves, traveling at terrific pace between a transmitter and a distant receiver, almost always followed the shortest path on the surface of the earth, the Great Circle Path. Experimenters also found that certain antennas radiate or receive energy in some directions better than in other directions. In other words, some antennas exhibit directional characteristics.

Basic Apparatus

One of the experimenters, Dr. Lee DeForest, developed a loop antenna which consisted of a rectangular, wooden frame around which was strung a coil of wire. DeForest found that when he connected this loop antenna to a receiver and then tuned the receiver to a transmitted signal, he could vary the strength of the receiver's output by rotating the loop about its vertical axis. He discovered further that he could calibrate the settings of the loop in such a way that he could determine the approximate direction of the transmitter from which he was receiving signals by simply rotating the loop until little or no output could be obtained from the receiver. Thus, by connecting a directional antenna to a radio receiver, DeForest employed the basic apparatus of a radio direction finder.

Modern Equipment

Radio direction finding with the apparatus and techniques of the present day presents a striking contrast to the simple, basic sets used by early experimenters. Long years of trial have brought forth new ideas, many of which have been incorporated in the design of the modern radio direction finder. Today the radio direction finder is highly specialized equipment with a variety of unique devices and circuits added to increase its accuracy, dependability,

HIGHLY SPECIALIZED TRAINING IS NECESSARY BEFORE ELECTRONIC TECHNICIANS CAN OPERATE AND MAINTAIN THE MORE COMPLEX RADIO DIRECTION FINDING SETS. BY MEANS OF TWO OR MORE RADIO DIRECTION FINDERS OPERATING ALONG AN ORIENTED BASE LINE, A "FIX" CAN BE OBTAINED ON RADIO TRANSMITTERS FROM WHICH SIGNALS CAN BE RECEIVED.

and usefulness. The type of equipments range from compact, hand-carried sets to somewhat larger, vehicular installations and highly complex, physically large sets for fixed station operation, the latter types usually making use of instantaneous bearing indicating devices such as meters and oscilloscopes.

Direction and Position

A single radio direction finder, after proper orientation and calibration, can be used for a myriad of purposes. By tuning in on just one station of known location, the direction from the direction finder to the station can be determined, thus making possible, by means of plotting on a suitable map, a determination of the *direction* of the North Pole of the earth with respect to the direction finder. Thus, a radio direction finder performs the same functions as the magnetic compass.

After plotting the directions of two or more transmitters of different bearings or azimuths, it is possible to determine the location of the direction finder. Thus, the apparatus finds, easily and quickly, *location or position*, a determination of which has previously required the use of celestial navigation.

Radio direction finding operating systems are extensive and complete. The apparatus is quite reliable when used in practically any part of the earth. Virtually every ocean-going ship and many types of aircraft are equipped with an "electronic navigator," the radio direction finder.

Military Applications

Militarily, the direction finder has a variety of applications.

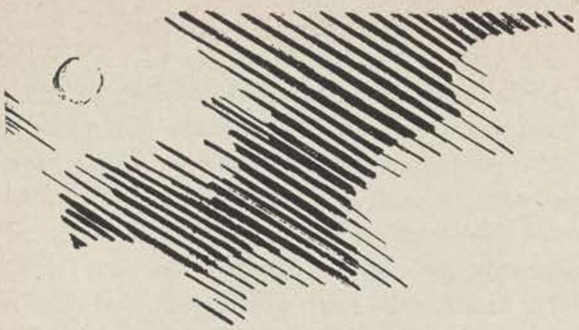
In the air, difficulties in navigation are introduced by the high speed of aircraft, movement over unknown terrain, and poor visibility caused by fog, low clouds, snow, or rain. These difficulties are overcome to a great extent by the application of automatic radio direction finders to facilitate rapid positioning and homing.

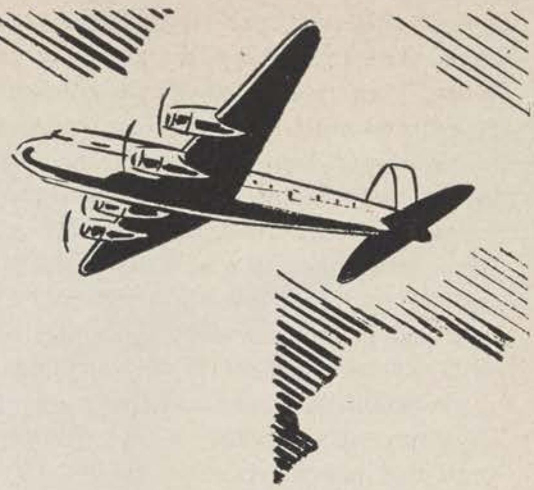
Positioning includes tactics for guiding fighter craft to the most favorable position for effectively intercepting the enemy in defensive situations or for carrying out air attacks. Homing fighter aircraft after contact with the enemy is another use of radio direction finders.

Direction finding equipment is also used for air-sea rescue service and has made possible the saving of countless lives.

On the ground, direction finders are used for positioning and homing of patrols and cavalry reconnaissance units, for the regrouping of airborne troops after landing, and for similar employment. Such usage requires apparatus that is small and light enough to be carried by one soldier.

In combination with radio communications intercept stations, radio direction finders are extremely useful for the purpose of analyzing enemy traffic (radio) and determining the enemy order of battle. The information obtained from this type of operation is invaluable. Radio direction finder sets employed in this service are usually of the more complex type, permitting a high degree of accuracy to be achieved.





Section Six

RADAR

Scarcely a man, woman, or child living in the United States at the end of World War II had not heard of *Radar*, the machine which had the penetrating eyes of "Superman"—the machine which could see through the darkest of dark, the densest of fog, the worst of storms; the contrivance which could see into the distance at ranges far beyond the limits of human vision. Radar was the apparatus which had detected the approach of enemy airplanes and warships and which had saved Britain in her hour of need.

Near the end of the war, the secret of radar was told, and such uncommon words as pulses, beams, microwaves, paraboloids, azimuth, and range found overnight acceptance in the language. Newspapers competed to present this new and seemingly mythical invention in the easiest-to-read manner; radio stations took up the explana-

tion of this new marvel; magazines were published with full-color illustrations of "Radar at Work." In fact, even the amazing-story type magazines could find little to surpass its amazingness—nor could the dramatic and breathtaking comic strips refrain from including this new phenomenon in their coverage. It was a fascinating story of a new invention which had become so important for early victory in the war that millions of man-hours and billions of dollars were spent on its development. In fact, more scientific man-hours were spent on the development of radar during World War II than had previously been spent on the entire development of radio communications.

Under such impetus, radar, a baby at the outset of World War II, grew so fast that it had become a "little giant" by the time our forces invaded France from England on D-day. It is convincing to realize that practically every bomb dropped by certain airplane squadrons in advance of our landing forces was aimed by means of radar—the radar which searched out with its X-ray eyes the location of enemy encampments—and all this without the infliction of a single known Allied casualty as a result of wrong bomb aim.

Radar was used for practically every bombing excursion in the European and Asiatic theaters of war—for the protection of our Fleet, for the safe passage of our troop transports, for the extermination of enemy submarines which had, at the outset of the war, exacted such a heavy toll of Allied life and property. Yes, radar was the dependable weapon of those upon whom this Nation had entrusted her existence; and a most valuable weapon it turned out to be.

Peacetime Uses

Even though the contribution of radar to our Nation at war is incalculable, the potentialities of this new development to our peacetime living deems to be of even more tremendous importance. For cannot the radar beam search out mountains and other physical barriers in the paths of aircraft, ships of the seas, and vehicles on land—barriers to be avoided, barriers which in olden days might have accounted for many stories with tragic endings?

Radar has made possible many, many services which may, and undoubtedly will, add more and more ease and comfort to our daily lives.

The fantastic electromagnetic waves of Faraday, Maxwell, and Hertz have found another application.

The Building Blocks

Once the marvels of radio communications are accepted, it is not difficult to comprehend the operation of the radar system. Such things as the generation of invisible, electromagnetic waves by means of electronic apparatus, the radiation of these waves from an antenna, their propagation through space at the velocity of light, the absorption of the traveling waves by a receiving antenna and the re-creation of the intelligence carried on the "captured waves" by the radio receiver—all these basic radio marvels are utilized in the operation of the radar system.

Radar also borrows from the knowledge of radio direction finding experts information regarding the directional properties of antennas and regarding means of indicating direction of

FLYING RADAR SETS GIVE THE NAVIGATOR AN ALL-IMPORTANT INDICATION OF UNDERLYING TERRAIN EVEN DURING THE MOST ADVERSE WEATHER CONDITIONS. THE RADAR "PICTURE" IS SIMILAR TO A RELIEF MAP AND, TO THE TRAINED OBSERVER, IS ALMOST AS REVEALING AS ACTUAL VISUAL INSPECTION.


213570

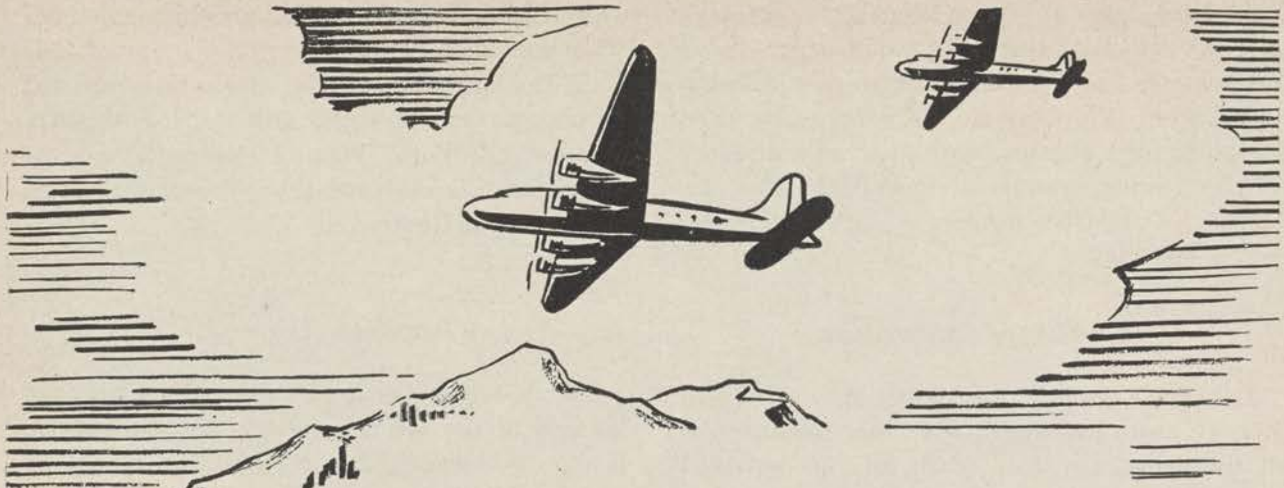
received waves by means of instantaneous azimuth indicators, such as meters and cathode-ray oscilloscopes. Radar draws from other phases of electronics and then, for good measure, adds a number of innovations.

Microsecond Indicators

The triumph of radar is its ability to measure time intervals of extremely short duration. A modern radar can measure, in terms of voltage, a time interval as brief as one-millionth of one second, or, as the radar technician states, one microsecond. Furthermore, radar indicating devices make microsecond measurements as simple as the reading of the second hand of an ordinary pocket watch.

Basically, radar is possible because high-frequency electromagnetic waves, upon leaving the transmitting antenna, can be focused into a beam of energy much in the manner in which light is focused by a searchlight; radar is possible because these high-frequency waves are deflected from their normal straight-line path upon collision with solid bodies or masses, such as buildings, mountains, airplanes, and surface craft; radar is possible because part of the energy in the traveling wave, after colliding with an object, is reflected and reaches the antenna from which the waves were initially launched; radar is possible because of the fact that electromagnetic waves travel through space at a known and constant speed—186,000 miles per second, the velocity of light.

Radar is made practical because scientists, engineers, and technicians were able to discover these possibilities and then envision, build, and operate a galaxy of intricate devices by means of which the possibilities could be utilized.



Section Seven

LORAN

In Nova Scotia, Newfoundland, Greenland, and Labrador; near Barrackspore, Kanjchrapara, and Kunming within range of Asia's famous "Hump"; and in virtually all coastal regions of the world, there are new kinds of radio stations, called *lorans,* in operation. The loran transmitters, performing in "master and slave" pairs, send out synchronized pulses of r-f energy carrying vital navigational information to special loran receivers installed on distant aircraft and seacraft.

Pulses of Energy

Some navigational functions of radio direction finding equipments are duplicated by lorans. However, the principles of operation for the two systems are different. Whereas the radio direction finder uses directional antennas to determine the angle of arrival of received radio waves, the loran receiver uses microsecond indicators to show the time difference between pulses of energy received from two or more loran transmitters at

different locations. Great accuracy is obtained in loran computations, the average errors being as small as those encountered during celestial navigation. For example, the error is less than one mile for a routine loran "fix" at a distance of 700 miles between transmitters and receiver. At shorter ranges, still greater accuracy is obtained.

A Military Innovation

Conceived during the early days of World War II, loran was developed under the auspices of the armed services. With its high-powered transmitters radiating medium-frequency radio waves, loran found its greatest military usefulness in long-range navigation. The first installations were on naval vessels assigned to escort freighters across the Atlantic Ocean. Later, loran coverage stretched over the Atlantic, across North America, and beyond the broad reaches of the Pacific. To attain such coverage, over 100,000 loran naval and airborne receivers were procured.

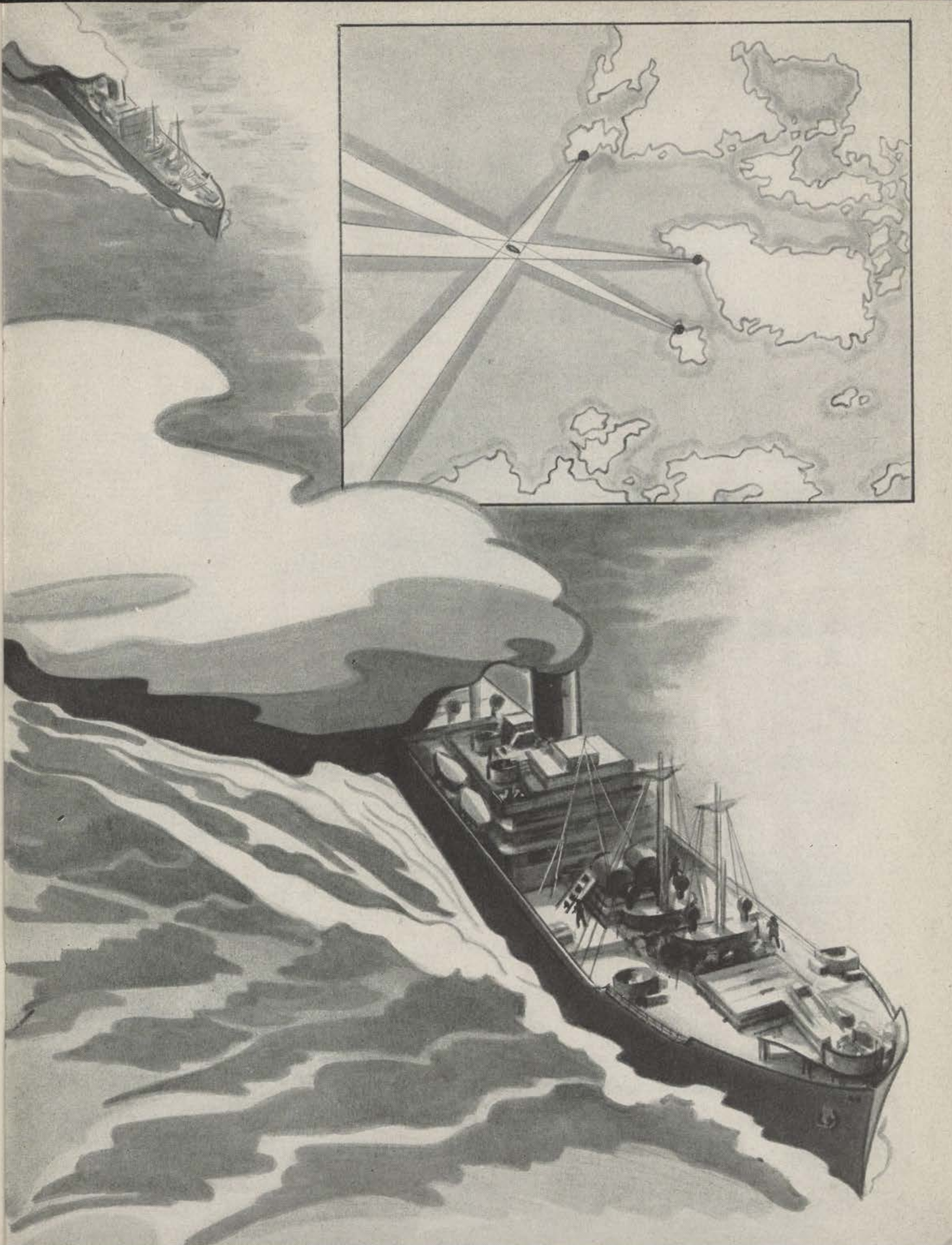
At the end of hostilities, loran was released to commercial carriers, and it now appears that, of all World War II electronic innovations, loran is destined to render the greatest service to navigation.

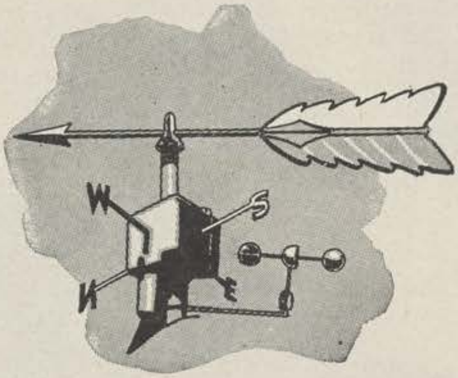
Another Triumph

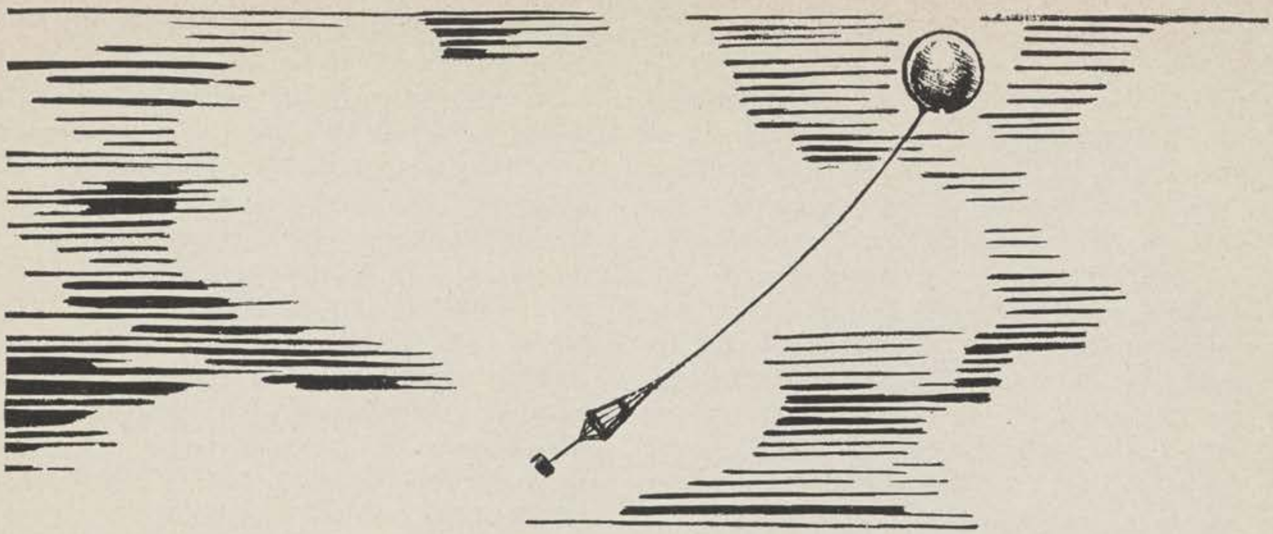
Today, loran operators on board ships of the air and of the sea rely on the electromagnetic beams produced by the pulsed loran transmitters and on the indications of their loran receiver "scope" for information from which they can plot their location on the loran chart, a grid of hyperbolic lines.

Thus, another electronic wonder has been placed at the disposal of voyagers; another triumph has been achieved by the men of electronics.

AS ELECTRONIC TECHNICIANS KEEP HIGH-POWERED, LAND-BASED LORAN TRANSMITTERS OPERATING 24 HOURS A DAY, OPERATORS ON BOARD SHIPS USE LORAN RECEIVERS TO DETERMINE THEIR POSITION ON THE HIGH SEAS AND THEIR DIRECTION OF TRAVEL.




W
S

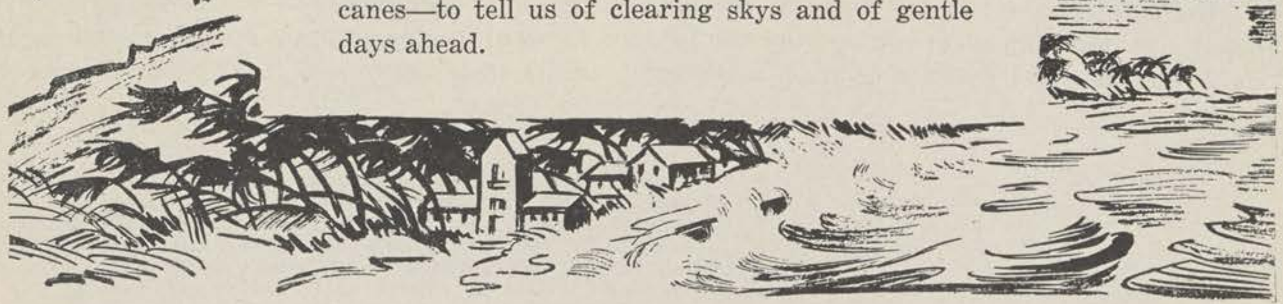


Section Eight

METEOROLOGICAL ELECTRONICS

The use of electronic equipment as an adjunct to the science of meteorology has opened another chapter in the story of electronics, a new chapter that may well be the most compelling of any within the electronics story. For meteorology is concerned with the atmosphere which surrounds our whirling globe; meteorology is concerned with direction up—a mile above the ground, two miles, five miles, ten, twenty, fifty, a hundred miles—up into regions as yet unexplored, up to new frontiers which hold forth the promise of new and startling adventure.

In meteorological electronics, we witness electronic equipment coming to the aid of the weather forecaster, the man whose job it is to know the weather—to predict tomorrow's weather—to warn us of approaching storms, gales, and hurricanes—to tell us of clearing skys and of gentle days ahead.



Swallows Fly High

Long ago, folklore was the basis for most weather predictions. These predictions, credited to farmers, sailors, shepherds, and others, were passed from generation to generation and undoubtedly contained findings based on countless weather observations. Some of these predictions are credible in their general accuracy but all are subject to extreme error when applied to specific land or sea areas. In the folklore predictions can be found such expressions as "Swallows fly high in good weather and low before a storm" and "If lightning appears to the north, east, or south, the storm will not reach you."

Following the era of folklore and the weather almanac, the science of meteorology took more firm footing with the inventions of the thermometer, the barometer, and the hygrometer, instruments for measuring the condition of the atmosphere—basic instruments without which the forecaster would still have to depend solely on wind and cloud observations. Following these inventions, new possibilities were explored and more accurate knowledge was obtained. Weather forecasts became more dependable but were still subject to considerable error. More information was necessary before the forecaster could hope to contend with an endless variety of weather conditions—with the tremendous scope of the weather process. Just how numerous the weather problems are may be gleaned by consideration of some elementary facts concerning the earth's atmosphere.

The Trade Winds

First of all, the sun is constantly drawing enormous amounts of moisture from the land and sea—moisture which rises from the warm earth to the cold heights of the upper air regions where it condenses and forms the clouds in the sky—moisture later returned to earth in the form of rain or snow. As this excursion continues endlessly, billions of tons of moisture and gigantic volumes of air are on the move; and the weather process is occurring—weather is in the making. This process would most likely be genial and uniform always were it not for sets of striking contrasts and a number of more or less violent factors. For example, equatorial lands give up immense amounts of heat while the polar ice fields remain frigid throughout the year; trade winds and other global movements of air result. The earth, in making its daily rotation, is constantly spinning from west to east with terrific surface velocity—over 1,000 miles per hour at the equator. Over three hundred volcanoes are now active. In short, many factors combine to make weather a temperamental, fretful, and unstable thing. This then is a picture of weather—sometimes violent, sometimes gentle, but always exhibiting an almost infinite variety of moods.

Worldwide Weather

Into this picture came the men of electronics to give important assistance to the weather prophets. They first presented the forecaster with electrical communications by means of which a collection of worldwide weather data could be speedily obtained. No longer did the forecaster have to be content largely with local measurements and observations; electrical communications networks enabled him to know current trends of weather in far-off places. And, since weather is worldwide in its makeup, this kind of information was revealing. A step forward was made. As a result, weather maps made their entry into the science of meteor-

ROCKET SHIPS LAUNCHED BY GROUND CREWS RACE AT A TERRIFIC SPEED TO CARRY ELECTRONIC DEVICES INTO THE REMOTE REGIONS OF THE EARTH'S ATMOSPHERE. THE EFFECTS OF THE IONOSPHERIC CONDITIONS ON THESE INSTRUMENTS ARE TRANSMITTED BY MEANS OF ELECTROMAGNETIC WAVES OF ENERGY TO TECHNICAL OBSERVERS ON THE GROUND WHO INTERPRET THE DATA.

ology—maps which show weather conditions over large areas—maps which can show at a glance the state of global weather. Yet even this electronic system was not sufficient to enable the prediction of weather with certainty. Evidently still more atmospheric information was required.

Balloons

Again the men of electronics responded with apparatus for exploring the upper atmosphere—apparatus for indicating weather conditions in the higher altitudes. The forecaster now has pilot balloons equipped with tiny radio transmitters to send upward—transmitters which send back a continual flow of information concerning the temperature, pressure, and humidity of the upper air regions. The forecaster now has radio direction finding and radar sets to track the ascent of the balloon and to indicate its position in space in order that data concerning wind velocity and wind direction can be obtained. Electronic apparatus not only accomplishes these tasks but also provides the weatherman with an actual record of atmospheric conditions encountered by the balloon in its travel through the sky—an almost instantaneously printed record which can be rapidly evaluated by skilled predictors.

But what about these so-called upper regions of the earth's atmosphere? How do they differ from regions near ground level? Through what areas do the pilot balloon and radio transmitter pass, and how high do they ascend into the sky?

Into the Stratosphere

As the balloon leaves the earth and begins its journey upward, it first passes through the thousands of feet of space in which many kinds of clouds may exist. The balloon may ascend through fog and mist hanging just above the earth, through the low-level, dense, gray stratus clouds at about 1,800 feet elevation, or through the slightly higher, white, fair-weather cumulus clouds which often grow to great size and appear as white puffs of wool. Between 4,500 feet and 30,000 feet the balloon may pass by or through a gigantic cloud called the cumulonimbus, or thunderhead. At 30,000 feet elevation, sheets of tiny ice crystals, called cirrus clouds, might be encountered. But the cirrus height is only the first leg on the journey of the pilot balloon and its passenger, the tiny radio transmitter, which continue to climb to elevations as high as 100,000 feet, or 20 miles above the earth.

Higher than the cloud level, starting at about 35,000 feet and extending all the way up to about 45 miles in height, is the stratosphere, a region of very thin air, low pressure, intense cold, and violent cosmic radiation. Below the strathosphere lies 96 percent of the earth's atmosphere. In the strathosphere, unprotected human life is impossible. It was into this region that a specially designed balloon equipped with a sealed gondola carried Captains Orville A. Anderson and Albert W. Stevens. This balloon, the Explorer II, went up into the stratosphere to the greatest height ever reached by man, 72,395 feet. Yet above this height and into the ozone region of the stratosphere goes the weather balloon before it completes its upward journey.

Into Space

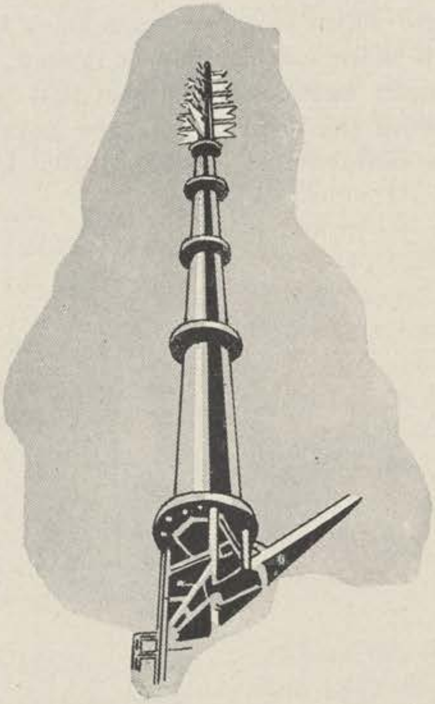
Above the stratosphere and extending from 48 to 180 miles above the earth are a series of gaseous layers called the "ionosphere." It is believed that these layers filter much of the cosmic and corpuscular radiation of the sun—that in these layers is formed the aurora borealis, or northern lights, often observed in the sky on warm summer nights. These are the layers from which certain sky-bound radio signals are reflected and bent back to the earth to make possible long-distance radio communications. These are totally unexplored regions of the atmosphere of which little tangible information has been obtained.

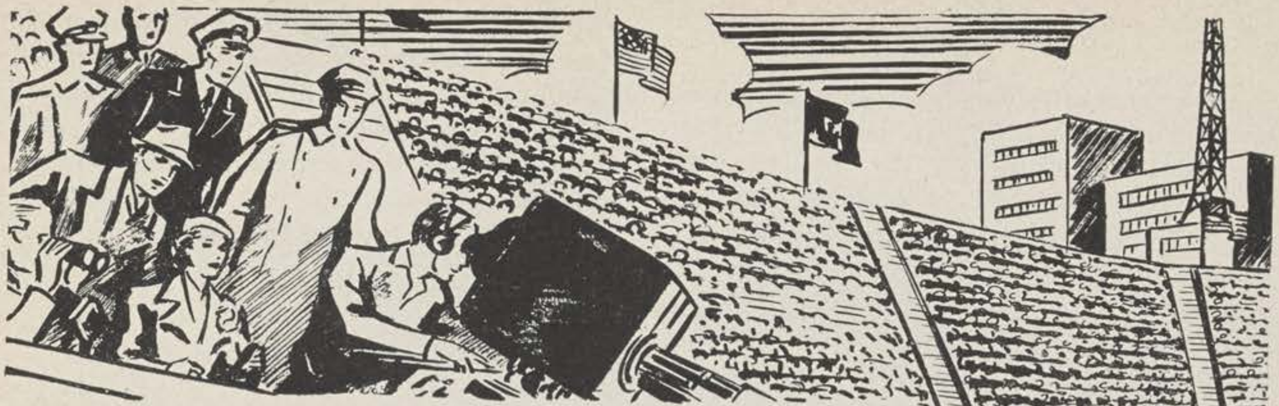
Above the ionosphere is the great expanse of space which makes up most of the area of our universe and out in which are the sun, the stars, the moon, and other heavenly bodies.

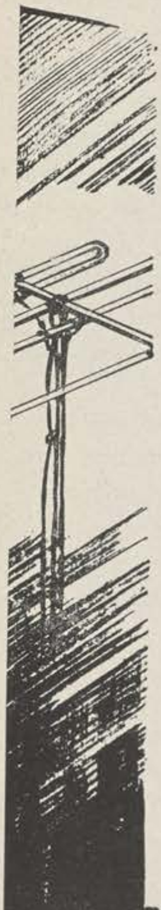
Another Challenge

This then is the story of the upper regions, the study areas for the meteorologist, the habitat of the dust devils, St. Elmo's light, black lightning, and the aurora borealis. This then may prove to be the great testing areas for new electronic equipments. For even with the pilot balloon and its associated electronic apparatus, the story is not ended, because rocket ships are making their entry into the scheme of things—ships which go higher and faster than any other known vehicle—ships which will probably send radio signals back to the earth, signals which will undoubtedly carry messages telling of phenomena in and above the ionosphere—messages with contents never before revealed.

And as if the rocket ship were not enough, electronic technicians are now sending electromagnetic pulses of energy to the moon—pulses which not only reach the moon but are actually deflected and returned to earth to be detected and identified. Where will this story end—at the moon, at Mars, at Neptune? What will be the findings at higher level—possibly a greater knowledge of cosmic and corpuscular radiation—possibly a huge store of knowledge with which to mold new basic concepts for the scientific order of things? It may be that no human being will ever know the secrets of the upper regions. As for the present, it can surely be said that we have only scratched the surface; we have only begun to learn; we have only started to explore.







Section Nine

TELEVISION

In a little telegraph terminal for the Atlantic Cable on the coast of Ireland, in 1873, an obscure telegraph operator named May made a discovery which was to have far-reaching effects on the eventual development of television. May happened to notice that when the rays of the sun fell on a selenium resistance in his telegraph equipment, electric current flow in the circuits increased and caused his apparatus to behave in a peculiar manner. He also noticed that each time the sun's rays were blocked off from the selenium, the current flow decreased. In short, he discovered the photoelectric effect whereby light changes are converted to electrical changes.

This chance discovery initiated a whole series of experiments as men attempted to utilize the properties of selenium in the design of a practical television system—experiments which were to continue for more than half a century before acceptable television service could be realized.

Early Developments

A few years after May's discovery, a scientist named Paul Nipkow actually built a television set which made use of the light-sensitive selenium cell and a rapidly revolving 'scanning disc.' The machine was a failure because only feeble amounts of electrical quantities could be generated. (The vacuum tube had not as yet been invented to provide the means of amplifying the currents to a magnitude required for successful transmission and reception.) Nipkow's scanning principle, however, has been retained and is used today in modern television practice. Using this principle, the entire televised picture is not transmitted at one time. Instead, the picture is broken down into thousands of tiny, elemental areas which are transmitted in rapid sequence. The 'scanner' selects the area to be transmitted at each instant and determines the order of transmission. At the receiving end of the system, the areas are reassembled in their proper places by a similar process. The scanning is so rapid, with thousands of areas being covered each second, that the eye, because of persistence of vision, cannot detect the instantaneous reception of each elemental area. Instead, the picture is perceived as a whole.

The First Picture

By 1925, DeForest had invented the vacuum tube, photographic lenses and the camera had been developed, the motion picture had been created, and other contributing devices were available. Borrowing from these, and using many of radio's electronic techniques for the transmission and reception of electromagnetic waves, another television system was built—a television system which made use of the selenium cell and a mechanical scanning disc similar to that used by Nipkow—a system that worked and was successful in sending a recognizable picture from New York City to Whippany, New Jersey. Television was now on its way for certain; but the apparatus was a mechanical monstrosity, a collection of motors, discs, and gears. Although the pictures were of poor definition, a televised picture had been successfully transmitted and received—a start had been made.

Electronic Television

During the 30's, mechanical scanning was replaced by electronic scanning, a system which makes use of electron camera tubes for the television transmitter and electron picture tubes for the television receiver. With the development of these tubes and their associated circuits, plus the utilization of higher radio frequencies and the improved design of amplifier stages in the transmitter and receiver, practical television has been obtained.

Thus, in television, we now encounter a strange phenomena—that of invisible electrons producing visible displays.

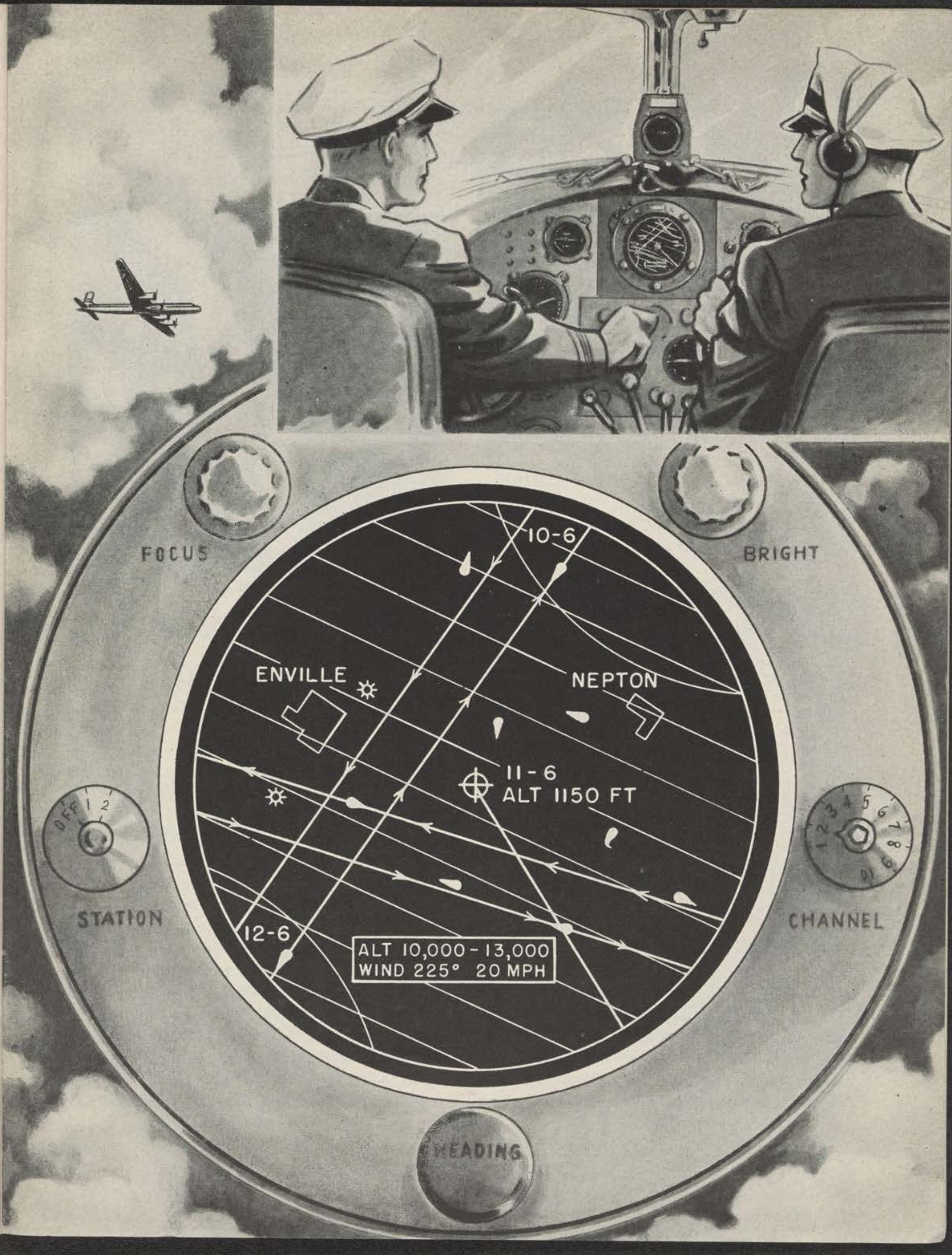
We witness an annihilation of space and time as the television receiver brings before our eyes a moving picture of events currently happening in distant places. Musicals, sporting contests, national conventions, dramas, and a variety of other events are well within the scope of the television service.

We find a new military device of high strategical and tactical importance—a device applicable to data transmission, reconnaissance, field maneuvers, map making, and a myriad of other uses.

We behold a new medium which seems destined to encompass the world—a medium with potential power almost too staggering to imagine.

Again, modern electronic wizards have uncorked a modern genie. Mighty electrons are on the march.

AN ELECTRONIC NAVIGATIONAL SYSTEM FOR AIRCRAFT, PROPOSED BY THE AIR FORCE, IS "TELERAN." IN THIS SYSTEM, AIRPLANES IN FLIGHT RECEIVE A COMPOSITE, TELEVISED PICTURE WHICH SHOWS THE POSITION OF THE AIRCRAFT IN SPACE, THE POSITION OF ANY SURROUNDING AIRCRAFT, AND OTHER PERTINENT DATA SUCH AS WIND VELOCITY, WIND DIRECTION, AND ALTITUDE.


FOCUS
BRIGHT
10-6
ENVILLE
NEPTON
11-6
ALT 1150 FT
STATION
CHANNEL
12-6
ALT 10,000-13,000
WIND 225° 20 MPH
HEADING

Section Ten

THE ELECTRONICS PARADE

Out of the established properties of electrons in motion and electromagnetic waves in space—out of the notions of the profound thinkers and the eager talented tinkerers in this new science of electronics, hundreds of devices have been created. They have been molded from the magic that is telegraphy, radio, radar, and the other basic electronic systems; and, as might be expected, many of these instruments, in design and application, surpass the amazing techniques and accomplishments of their predecessors.

The reliable and much used FACSIMILE is a form of communications which is a direct and natural outgrowth of both radio and telegraphy. This important electronic device is used

TRANSMISSION AND RECEPTION OF MILITARY MAPS ARE IMPORTANT FUNCTIONS OF THE FACSIMILE SET.

to send and receive pictures over telephone lines or radio communication networks. By means of facsimile, pictures of events occurring in distant lands as well as throughout this country reach metropolitan newspapers in a few hours in time to appear on the front pages

HIGH-SPEED AND ACCURACY ARE OBTAINED WITH THE ELECTRONIC COUNTER.

of the next edition. Facsimile played its part in the war by its ability to transmit maps and directions.

One piece of apparatus which has already found wide usage in industry is the ELECTRONIC COUNTER. This instrument has proved invaluable for counting applications which require both high speed and accuracy and which had been insurmountable by means of mechanical systems. Articles from pills to machine parts are counted, no matter how fast they are emitted from the machine which produces them. High-speed motion, such as the revolutions of a generator or motor, can be counted and recorded. By putting electrons to work, we not only can count the number of people entering or leaving a building, but even can open and close the door for them.

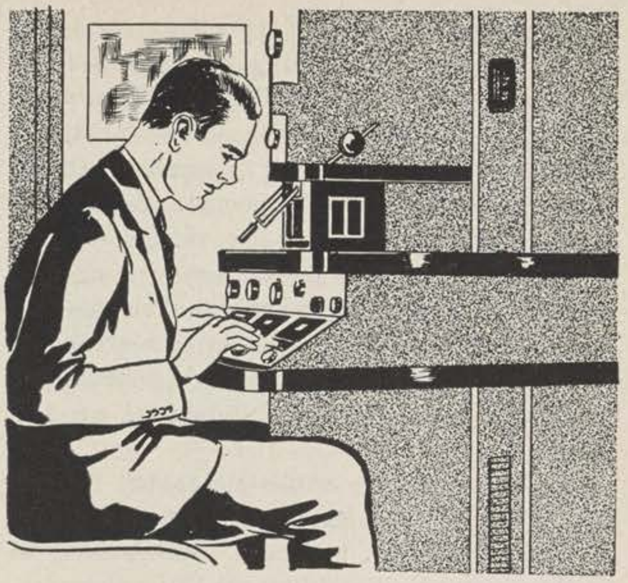
An electronic wonder appreciated by the researcher is the ELECTRONIC COMPUTER, an instrument which has done much to reduce the time required for the solution of mathematical problems and which has even enabled scientists to solve problems heretofore ignored. This electronic giant, which may consist of 30,000 electron tubes and a large roomful of gear, can add, subtract, multiply, and divide almost instantaneously. It can carry on several operations simultaneously and can retain the solutions of portions of problems under consideration until the information is needed.

Another Gargantuan electronic achievement is the ELECTRON MICROSCOPE. This instrument is the latest step in that procession of instruments designed to expose the world of Lilliput. Far surpassing the magnification powers of the ordinary light microscope, this equipment has created a new branch of science called electron optics and has been responsible for the findings of much new data in industrial

BY FAR THE LARGEST AND MOST COMPLEX OF ELECTRONIC DEVICES IS THE ELECTRONIC COMPUTER.

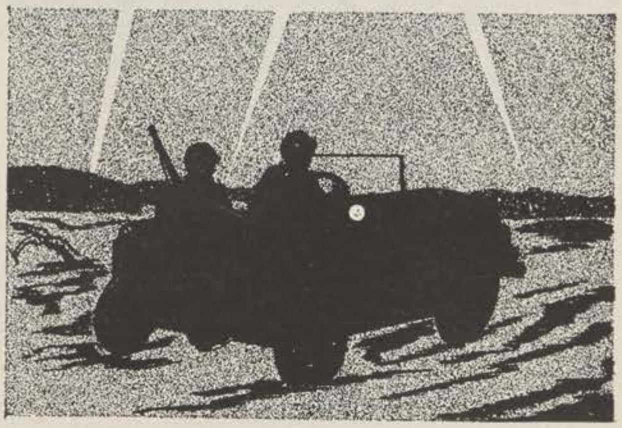
and scientific fields. Through the use of the electron microscope, particles of matter a thousand times smaller than the head of a pin can be enlarged to the size of a baseball. In fact, this microscope is capable of magnification so great that, with it, the atomic arrangement of matter can be studied.

Truly remarkable feats are also being per-



TREMENDOUS MAGNIFICATION IS OBTAINED THROUGH THE USE OF THE ELECTRON MICROSCOPE.

formed by a number of so-called INFRARED DEVICES which utilize focused-electron beams and infrared rays, plus an assortment of optical lenses and electronic gear. One such device, christened "Felix," is mounted in the nose of a bomb to control its trajectory and "steer" it to some heat-emitting target. Another device can locate an airplane in flight by detecting the heat radiation from the plane's exhaust. But perhaps the most incredible of all is the equipment that permits vision in total darkness—that enables drivers of jeeps and other vehicles to travel at full speed through darkness, without visible headlights.



VISION IN DARKNESS IS A TRIUMPH FOR INFRARED EQUIPMENTS.

SONAR EQUIPMENT is widely employed by our Navy for searching out and locating undersea craft. The DOODLE BUG, a magnetic type detector, performs similar functions. Not only can undersea craft be located with the Doodle Bug, but deposits beneath the earth's surface can be detected. By means of this equipment, prospectors now hunt for oil and other resources having magnetic effects associated with them. Vast areas can be searched in one day through the use of such instruments mounted underneath the fuselage of an airplane.

During the Battle of the Bulge, the PROXIMITY FUSE was used for the first time by our ground forces and was instrumental in halting an enemy breakthrough. This tiny electronic device mounted in the nose of a shell causes the shell to detonate upon reaching a desired location. Of the proximity fuse, General Patton remarked, "When all armies get this shell, we will have to devise some new method of warfare."

GROUND-CONTROLLED APPROACH systems are being extensively used at airports for guiding aircraft to safe landings during

RADAR AND RADIO COMMUNICATIONS ARE COMBINED TO FACILITATE "BLIND" LANDINGS OF AIRCRAFT.

conditions of poor visibility. By means of these systems, which combine radio communications with radar, many thousands of planes have been "talked in" to perfect three-point landings despite adverse weather conditions.

ABSOLUTE ALTIMETERS are now installed in airplanes to indicate elevation above underlying terrain. This has increased flying safety.

RADIO-CONTROLLED DEVICES perform a variety of functions, including the control of pilotless airplanes, crewless seacraft, and driverless motor vehicles. Many technical experts agree that eventual development of radio-controlled "winged missiles" may obsolete

"WINGED MISSILES" MAY OBSOLETE MANY FUNCTIONS OF MILITARY AIRCRAFT.

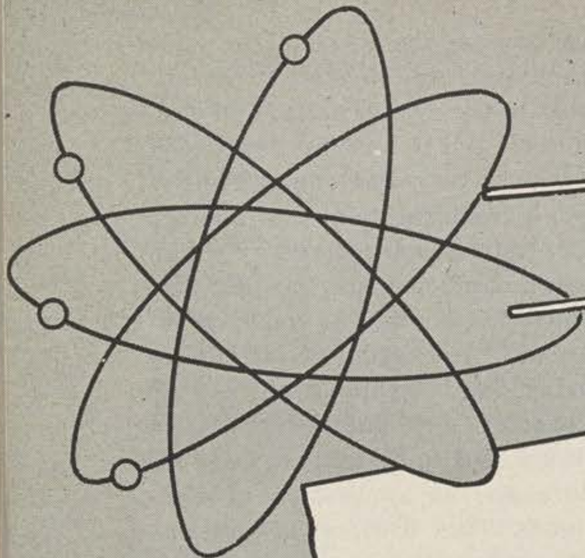
bombers as mediums of long-range offensive action and fighters as mediums of ground-to-interceptor defense.

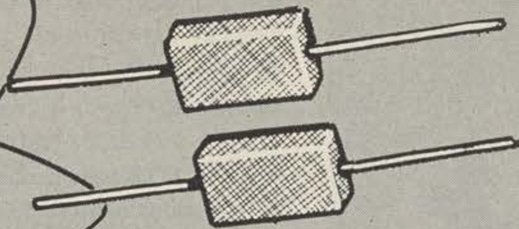
For years, X-RAY MACHINES have been invaluable for purposes of medical diagnosis and in surgery. Now, the application of X-rays has been multiplied. Million-volt potential machines have been built which are capable of "seeing" through five inches of solid steel; of determining the construction of matter—fibers of wool and other textiles, metal alloys for aircraft, rubber goods, and lubricating oil.

DURING OPERATION OF 1,000,000-VOLT, X-RAY MACHINES.

GIANT CYCLOTRONS ARE BASIC INSTRUMENTS FOR THE NUCLEAR PHYSICIST.

With that famous atom-smashing machine, the CYCLOTRON, scientists working in the field of nuclear physics are now able to make changes in the structure of matter. In the vacuum chamber of the cyclotron, it is an electron stream that is used to initiate the train of events which terminates when one element is changed, through transmutation, into another—it is powerful radio-frequency energy which excites a gigantic electromagnet, causing ions to be accelerated to the terrific velocity re quired for successful bombardment—it is electronic measuring instruments, such as the proportional counter and the Geiger-Muller counter, which are used to detect nuclear products. Thus, through the application of electronic techniques, the dreams of ancient alchemists are coming true.

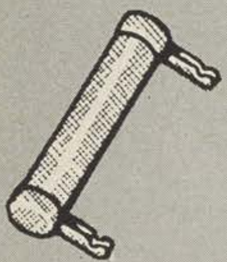


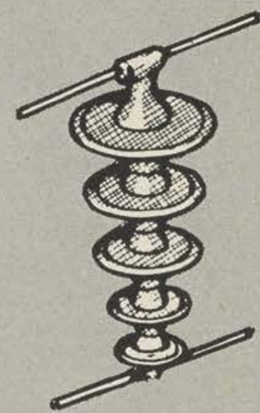


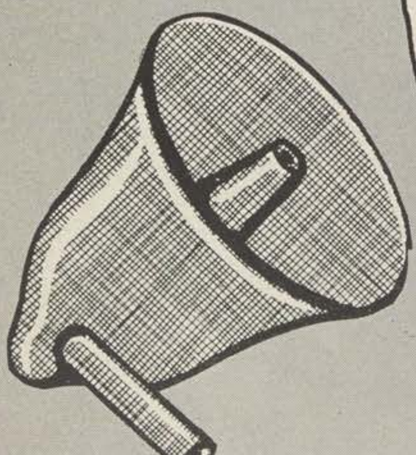
Conclusion

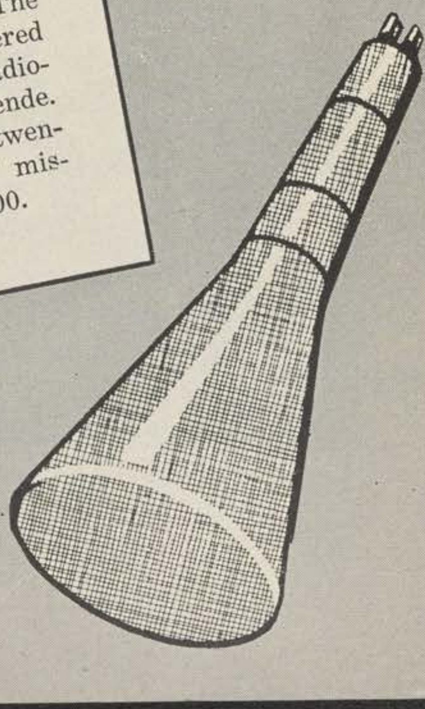
By 1895, the people of the world felt that their men of science were due for a long-deserved rest. It was the popular belief of the time that everything of importance had already been discovered and that the great inventions had already been contrived. With justifiable pride the scientific achievements of the eighteenth and nineteenth centuries were considered the ultimate in all that could possibly be accomplished in the universe. The predictions of the era were that future generations would have to be content with making minor refinements and rearrangements to the established order of science.

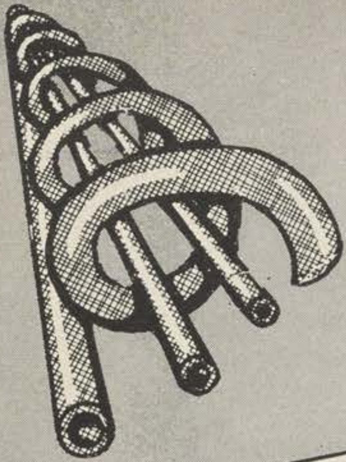
Within the past fifty years, the events which have transpired prove how erroneous were these predictions. Even before the celebration which marked the arrival of the twentieth century, Pierre and Marie Curie had announced a discovery which was to have far-reaching effects and was to change the theories on the structure of matter. The Curies, working in France, had discovered radioactivity and had manufactured a radioactive element, radium, from pitchblende. The subsequent developments of the twentieth century continued to prove how mistaken were the predictions prior to 1900.

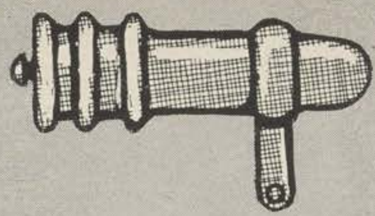


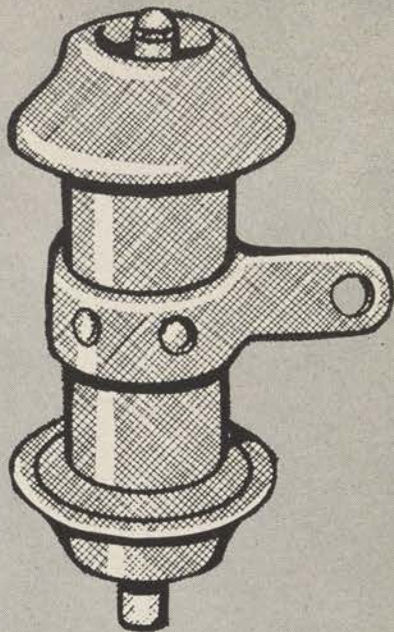






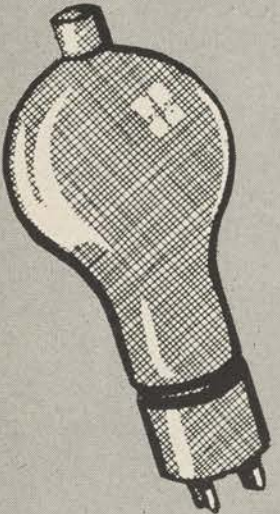


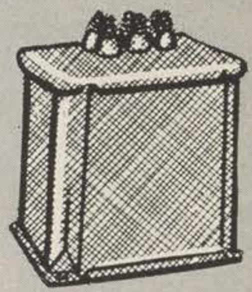


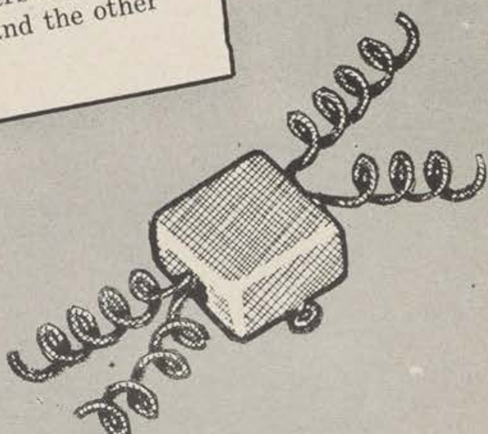


Today, men are eagerly searching for the undiscovered in electronic research. Men are at work exploring the known and unknown portions of the frequency spectrum—from sound waves to supersonics—from the lower radio frequencies to the ultra-high and micro-wave frequencies—through the infra-red, the visible, and the ultraviolet regions—up into the area of the X-rays and gamma rays, those minute wavelength radiations associated with radioactive elements. Men are reaching even into the spectrum heights of those fabulous cosmic rays. Out of this work, new techniques and instruments of electronic wizardy will emerge, but only after seemingly impossible problems have been solved. These solutions will require the careful thought and patient work of many people, whose findings will be correlated with other efforts, verified by experiments and aided now and then by sparks of genius to reconcile the irrational and so accomplish the impossible.

As a conclusion, a salute is given to all men of electronics and a greeting is extended to newcomers in the field. Through their zeal, new magic will be created from electrons in motion and electromagnetic waves in space. Through their initiative and industry, future accomplishments will be achieved to challenge those of Oersted, Faraday, Franklin, Bell, DeForest, and the other masters of earlier years.







☆ U. S. GOVERNMENT PRINTING OFFICE: 1949—838805