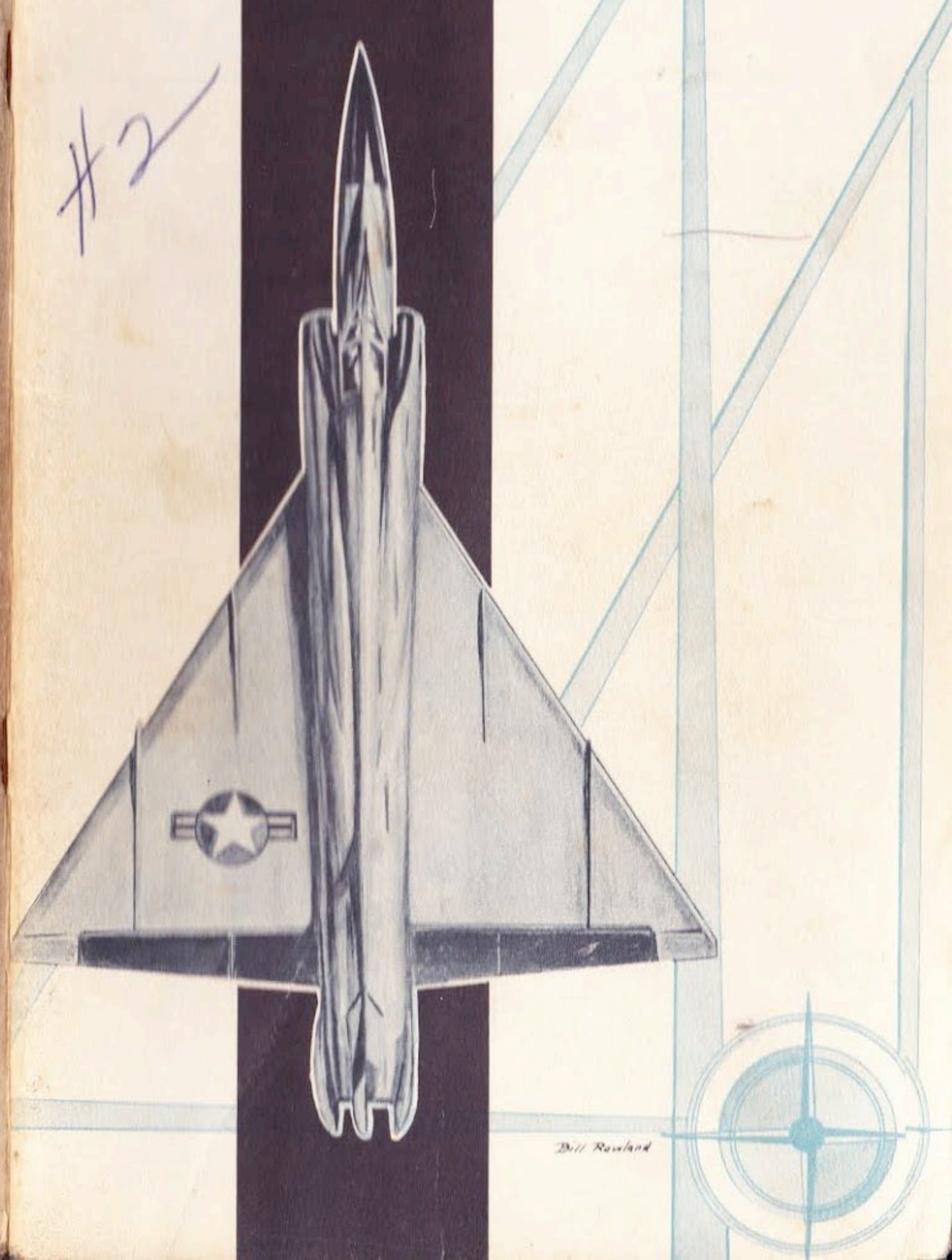
AIRPORTS AIRWAYS AND ELECTRONICS

#2



DESIGNED AND LITHOGRAPHED by HENNAGE • WASH., D. C.

James Card
810 minot ave.

By
Harold E. Mehrens

William E. Rowland
Art Director

AIRPORTS,
AIRWAYS,
AND
ELECTRONICS

CONTENTS

		Page
ONE	Growth and Development	1
TWO	The Charting of Airports and Airways	7
THREE	Electronics In Aviation	13
FOUR	Why Airports Are Necessary	23
FIVE	Airways, and the Facilities of Air Traffic Control	29
SIX	The Regulation of Air Traffic I	37
SEVEN	The Regulation of Air Traffic II	45
	Summary	55

Foreword

Current technological developments in different but related areas appear to be interdependent. Such is certainly the case with respect to progress in the field of aviation radio and that in the field of electronics generally. The use of radio in aviation has enabled aviation to broaden the scope of its operation and services. In order to handle the air traffic thus generated, new electronic devices had to be invented. Research directed toward this problem discovered not only new devices for air traffic control but also new devices whose application is destined to affect many other industrial fields.

New machines based upon electronic principles, whether used in aviation or elsewhere, have implication for broad education and training. A machine may surplant the man who does a menial task; man still remains the master of such machine. But men are not born with the knowledge and the skills such mastery requires. These must be learned. The foundations for their learning are the fundamental scientific ideas underlying the operation of the electronic devices which it appears will soon dominate the socio-economic scene.

The Civil Air Patrol seeks to assist those who would help youth bring both understandings and skills to the solution of the sociological problems which our scientific and technological advancement appears to have created. To this end it offers its services to organized formal education, and it supports a national youth movement. Its aviation education series will serve well to acquaint the high school student and the Civil Air Patrol cadet with information essential to the general understandings in aviation and many of its related fields.

WALTER R. AGEE
Major General, USAF
National Commander
Civil Air Patrol

Preface

Airports, Airways, and Aviation Electronics is one of a series of seven books prepared for use in the aviation education program of the Civil Air Patrol. It is to be used with an instructional 35 mm. color, sound filmstrip which illustrates the concepts which it introduces.

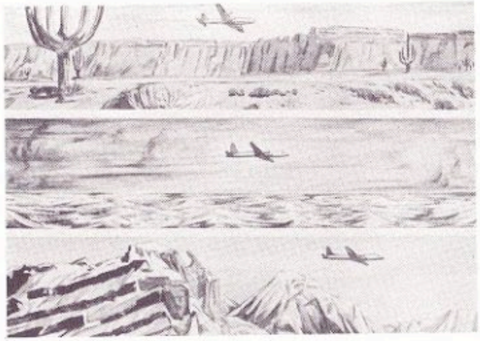
The purpose of his book is to describe in terms of secondary-school student understandings the scientific principles basic to airport and airway operations. The growth of airports and airways is reviewed. The aeronautical chart is presented as a source of information about airports and airways. A simple explanation is given of the radio circuit as the basic operational principle of the facilities of airway marking and of airport and airway traffic control. The nature of those electronic devices, which make possible the dispatch of airport and airway functions, is explained. Finally, the methods employed at airports and along airways to prevent air-traffic conflicts are discussed. The book's treatment of the several areas with which it is concerned is sufficiently general to be of basic importance to all aviation career objectives. Yet, its content is detailed enough to challenge the interest of students and adults alike.

Although its first use will be with Civil Air Patrol cadets, it will be found of considerable value in any science class or any other class that stresses the role of scientific concepts in relation to airports and airway operations.

The books and filmstrips of this series are not limited to use with Civil Air Patrol cadets only. They will be found of value to students and teachers in any aviation program. Those working with adults may also find this material helpful, if the instruction or information goal is general education as it relates to aviation.

The advice on technical matters received from the Civil Air Patrol Headquarters, Office of Operations and Training, and the advice on educational matters provided by the Aviation Education Personnel helped materially in the preparation of this book. Special acknowledgement is also due to Mr. Irving Ripps of the Civil Air Patrol, Office of Information Services, and to contributing members of the Civil Air Patrol National Commander's Aviation Education Committee for suggestions and advice offered. The names of the members of the three groups mentioned above appear elsewhere in this booklet.

MERVIN K. STRICKLER, JR.
Director of Aviation Education



CHAPTER ONE

GROWTH AND DEVELOPMENT

You have heard it said that an airplane can travel from any point on the surface of the earth to any other such point. In theory, this is true. In theory, such travel can follow a direct route. There are no surface obstacles such as mountains and deserts in the path of an airplane's flight.

The need for airports.

In practice, however, aircraft need airports and air lanes, just as ships need seaports and sea lanes. In the days of the pioneer pilot when aviation was very young, airplanes were all small and any cow pasture could be used as a "flying field." However, when the value of aircraft as a practical mode of transportation was recognized and when the military potential of aviation was understood, large airplanes began to be built. Airport growth had to keep pace with aircraft development.

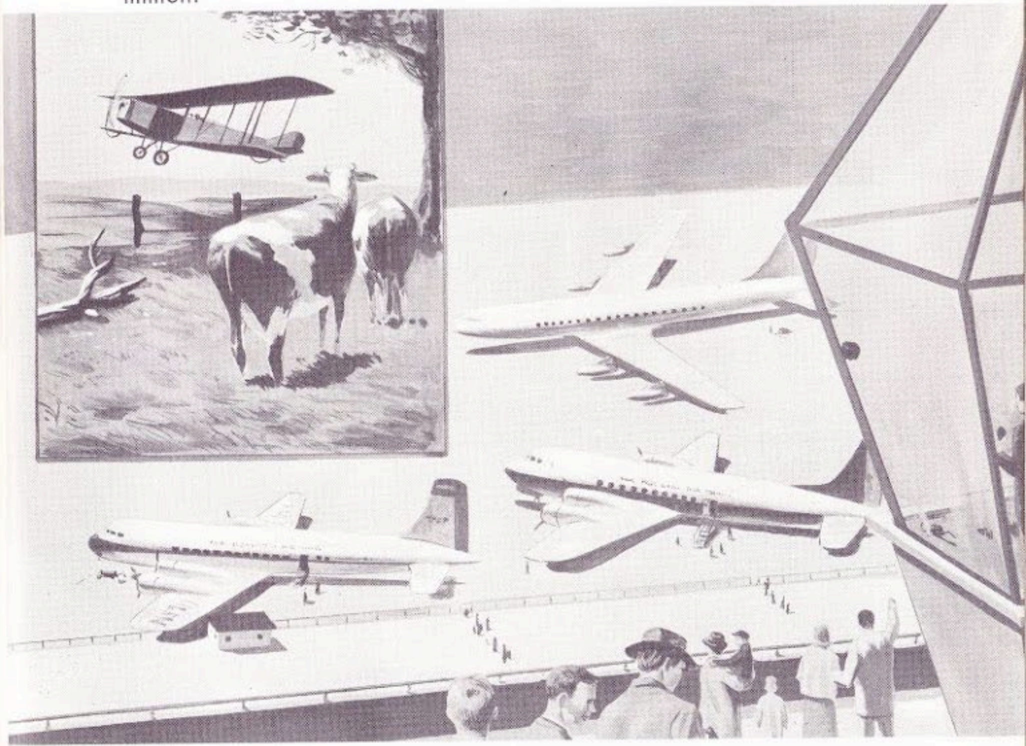
Airport growth.

Early *airports were merely sod fields designated as airplane landing* areas. When these proved inadequate, cinder and gravel runways up to 1500 feet in length were constructed. These were laid out so that aircraft had a choice of landing direction and could land into the prevailing wind. As larger aircraft were built and these airports, in turn, became inadequate, runways were lengthened and surfaced with concrete.

In 1928, only twenty-five years after the historic flight at Kitty Hawk, there were 1,300 airports of all types in the United States. Two years later, there were 1,800 airports of all types. However, only 600 of these were lighted and could accommodate night time, flight operations. Today there are about 7,000 airports of all types serving the cities and towns of this country. As a matter of fact, an airport of some type can now be found at intervals of 15 to 30 miles along most designated airways.

Airport growth and Federal Government aid.

It is likely that airport growth would have proceeded at a less rapid rate had not the Federal Government aided in the construction of airports. Such aid was first made available in the early 1930's. However, it was not until the passage of the Federal Airport Act of 1946 that a substantial aid program was set up. This act authorized a maximum expenditure of one-hundred-million dollars per year for airport improvement and construction. The Federal Aid Airport Program for the fiscal year 1958 involved 334 construction and improvement projects and the expenditure of over $55 million of Federal funds. The Federal Aid Airport Program of the fiscal year 1959 included 358 construction and improvement programs and an increase in Federal Government expenditure to approximately $64 million.



A modern airport.

Continued airport growth and development.

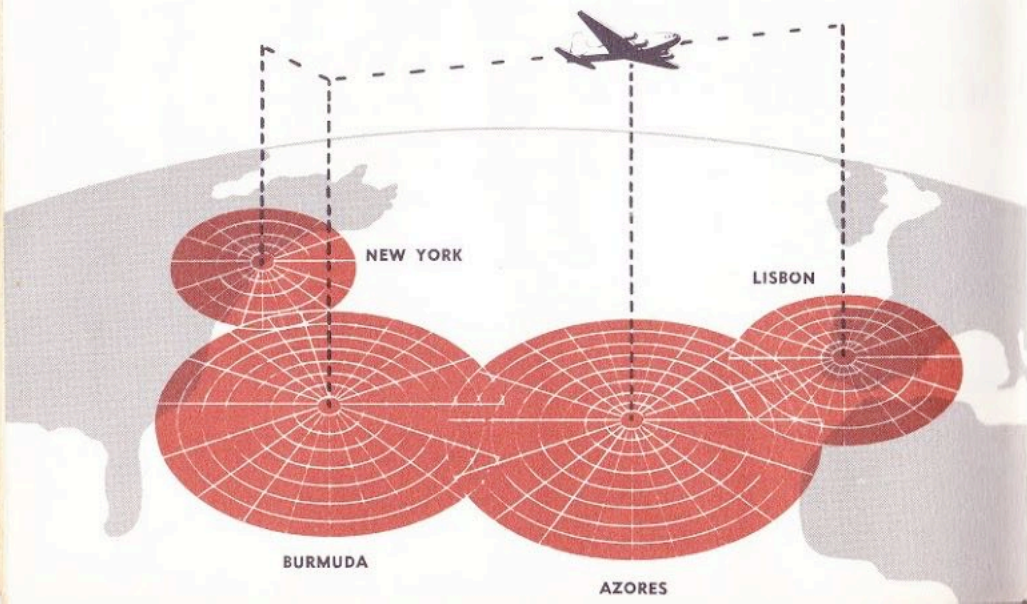
Airport growth is likely to continue for many years to come. Modern transport planes, powered by reciprocating engines, land at speeds up to 100 mph. In a few years, after jet propulsion comes into greater use, landing speeds of transport aircraft are likely to increase to 125 mph. A 100 mph landing speed requires a runway of approximately 6,000 feet. A landing speed of 125 mph will require a runway between 8,000 and 10,000 feet long depending, of course, upon whether or not improved changes are made in the landing and braking techniques now employed.

The purpose of airways.

Designated airways lead from airport to airport. They are marked to help the pilot or the navigator keep the aircraft on its course. Improvements in airway marking are made necessary by developments in aircraft and airport construction.

Early methods of airway markings.

In 1921, when Jack Knight made the first scheduled night flight, carrying mail from North Platte, Nebraska, to Chicago, Illinois, the flight path he followed was marked by bonfires on the ground.



Lighting of airways by powerful electric searchlights was begun the next year. By 1926, a line of these airway beacons, placed every ten or fifteen miles along the airways, extended from coast to coast. On a clear night, a pilot could see three or four lights ahead and, by keeping these in line, could stay on his course.

There were also route identification and course lights installed on the beacon towers. Identification lights, using the international Morse code, flashed an assigned signal at regular intervals. Course lights were fixed so that one pointed one way along the airway and another pointed in the opposite direction.

The radio signal and airway marking.

In 1919, two years before the first night flight of air mail, a research project in the use of radio in airplanes was undertaken by the University of Maryland. However, it was not until 1927 that radio ranges were used to supplement light beacons. The early use of these radio range stations was limited. Only seventeen were operating by the close of 1927. Today, over 400 are in operation. The marking of airways with radio broadcasting facilities progressed until by 1940 there were about 40,000 miles of air routes defined by four-course radio ranges.

Low frequency omni-directional range

(Intercontinental Navigation)

The growth of air marking.

A new system of airway marking.

The early 1940's saw the use of the four-course radio-range station* increase until at the end of the year, 1946, there were about 346 of these in operation. However, the number of aircraft using the airways also increased. Consequently, beginning with 1946, serious air-traffic problems began to emerge. After careful study was made of airway traffic problems and research and experiment had proven the capabilities of new electronic devices, a new system was put into use.

The new method of marking the airways of our nation could not replace the old methods all at once for some very practical reasons. One of these reasons was economic. Vast sums of money would be required to purchase new radio transmitting equipment for airways and radio receiving instruments for aircraft. Another reason was educational. Those using the airways had become accustomed to one system; they would have to learn to use a new one. The advent of jet-propelled aircraft and airway congestion resulting from increasing growth of both military and civil aviation made imperative adoption of modernized navigation and airway control procedures.

Rotating beacon lights still mark some airways; four-course airways are still marked by *four-course range stations;* yet, new designated air routes marked by radio-range stations which use equipment based upon the very high-frequency part of the radio spectrum are rapidly coming into use. About 500 VOR stations had been installed by 1956 and the Federal Government's air-traffic program called for installing several hundred VORTAC stations during the three years following.

---

* See Chapter V, p. 31.

CHAPTER TWO

THE CHARTING OF AIRPORTS AND AIRWAYS

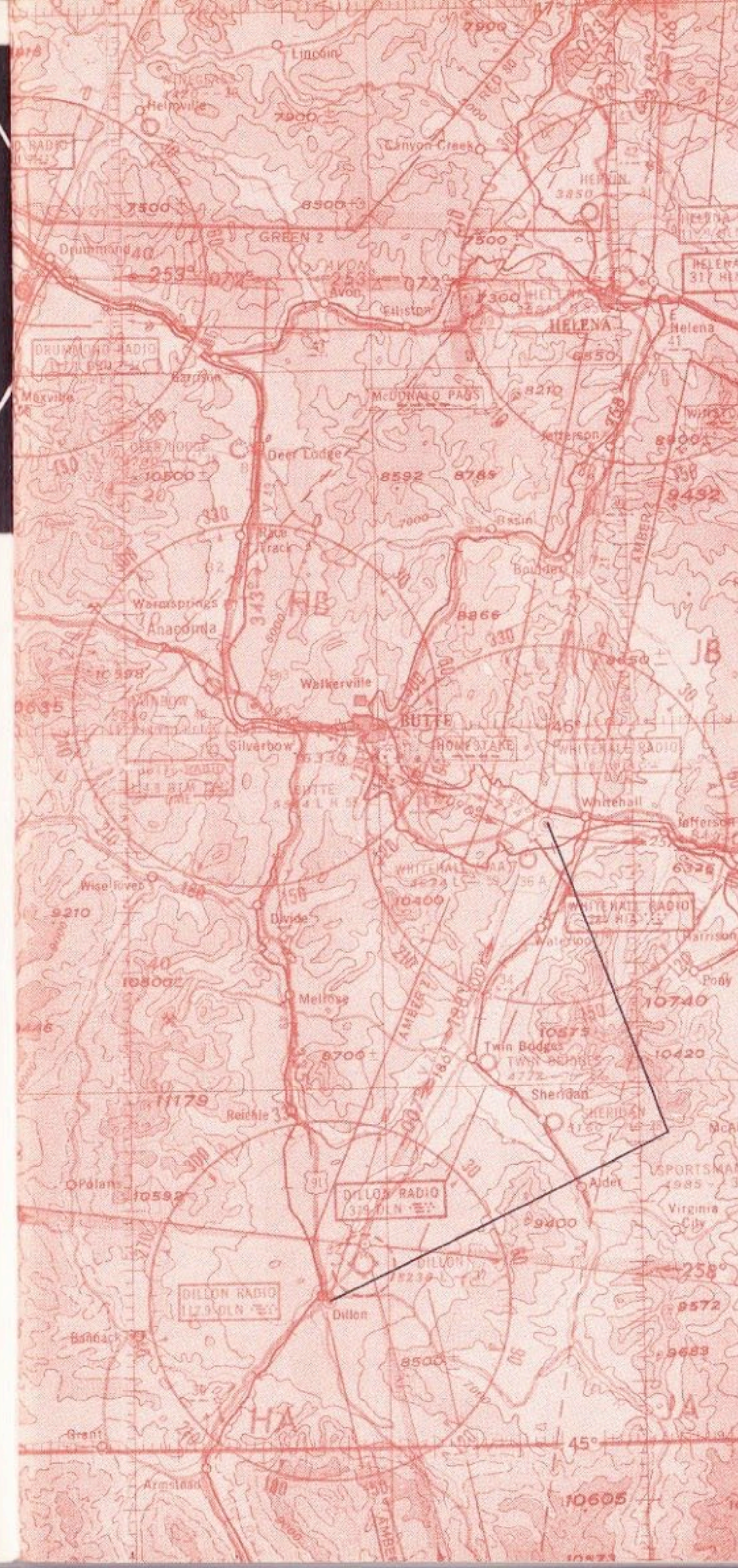
The importance of chart symbols.

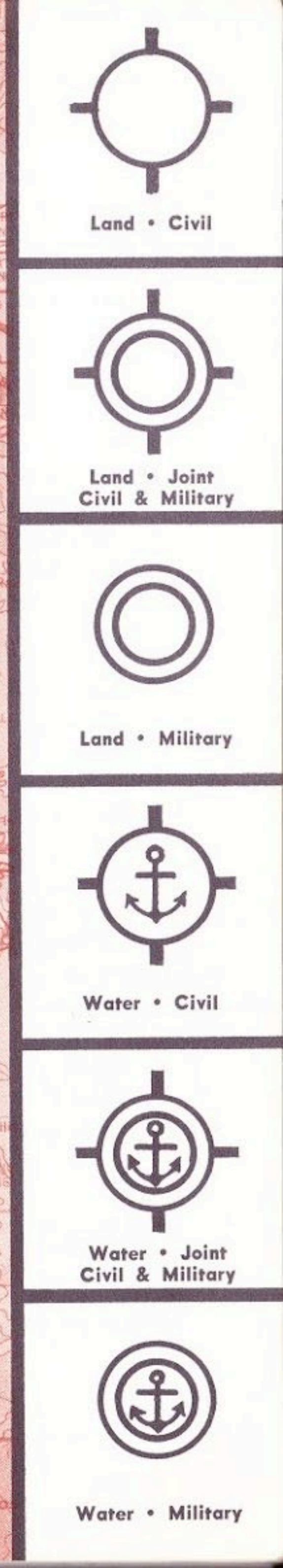
Aeronautical charts reveal much about airports and airways. For this reason and others, they are indispensable to pilots. However, before a pilot can use a chart efficiently, he must know how to read the symbols which he finds upon it.

It is important that you understand about the growth and developments of airports and airways. It is of greater importance that you are able, when the need arises, to learn other things about them from an aeronautical chart. In order to do this, you, like the pilot, must become able to interpret the symbols that the chart-maker uses.

Classification of airports.

The chart-maker calls airports and airbases (military airports) aerodromes. In addition to the method of *airport classification* which divides airports into public airports and limited airports, there are other methods of classifying aerodromes. (1) Airports or aerodromes are either for land planes, or sea planes. (2) They are civil, military, or joint (used by both civilian and military aircraft). (3) They are





for heavier-than-air craft, lighter-than-air craft, and helicopters. (4) They are equipped with traffic control and service facilities, or they are emergency aerodromes with no facilities. (See page 9.)

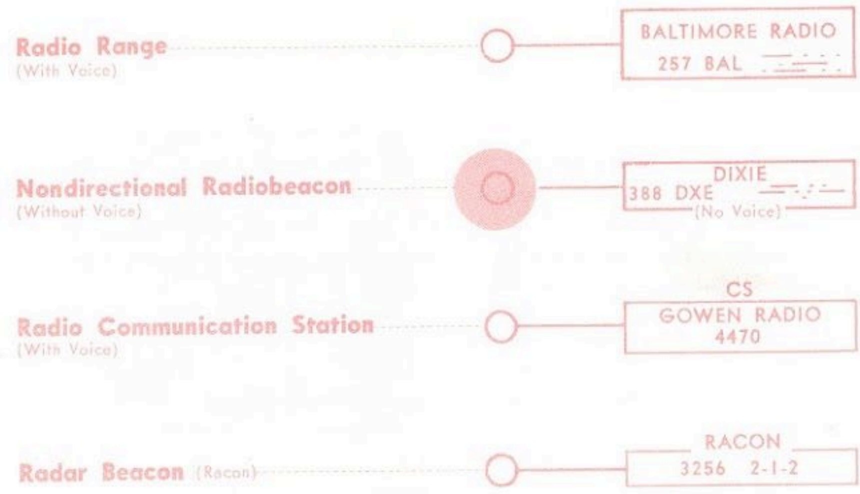
The chart and airport information.

You will remember that there is a relationship between air density and the altitude at which an airplane operates. At sea level airports the air is more dense than it is at airports having elevations of 500 feet, or more; for, as you remember, the higher the altitude, the less dense the air. You will also remember that air density has a relationship to lift, and that the less dense the air, the longer the "take-off" run or "landing-roll" required for aircraft operation. For this reason the pilot needs to know the elevation in feet of the airport he approaches.

There are other things he must know about the airport. His chart will tell him about most of these. His flight information manual, a Federal Aviation Agency publication, will give him information about the others, such as for example, recent changes in airports and airways facilities. The pilot can learn from his chart whether or not an airport is adequately lighted for night flight operations. He can learn the length of its longest runway, whether or not it has low-visibility approach systems, and whether or not there is a direction-finding station at the airport. (See page 30 for explanations of these traffic control facilities.) He can also learn from his chart the transmitting frequencies of the control tower, so that he can "tune-in" the proper frequency and receive information and instructions from the tower.

The *symbols used to disclose airport information* are presented in the following illustration. You will note that runway length is given in hundreds of feet and that a dash in the place of a symbol means that the facility in question is not available.

908	Elevation in feet
L	Minimum Lighting
H	Hard Surfaced runway
41	Length of Longest runway in hundreds of feet



The chart and airway information.

The radio ranges, beacons, communication stations and broadcasting stations are also shown on charts. Generally such stations are located near airports. If a radio facility uses the low/medium radio frequencies (LF/MF) the chart symbol will be printed in red; if it uses the very high radio frequency (VHF) the symbol will be printed in blue. If voice broadcast is included in the service provided, the word, "Radio," will follow the name of the airport near which the station or beacon is located.

Airways marked by LF/MF range stations are designated by the colors, Red, Green, Blue, and Amber and a number. Such an airway might be designated as Green 5 or Red 68. Airways marked by a VOR (Very High Frequency Omnirange) are called Victor airways. They are designated by the letter V and a number. Victor airways which extend in an easterly-westerly direction employ even numbers; those in a northerly-southerly direction, odd numbers. Other controlled civil airways indicate direction by use of names of colors. Red and green airways extend easterly-westerly; blue and amber, northerly-southerly.

Chart symbols of surface obstacles and caution areas.

Although the path that the aircraft flies is through the air, the airplane pilot must still pay heed to many kinds of surface obstructions. Some of these are natural obstacles to safe flying, such as mountains; others may be obstructions which are man-made, such as high towers and transmission lines. The *chart symbols* for these must be readily recognized. Caution areas, danger, restricted, and warning areas, and prohibited areas are all significant in terms of airway mapping. (See illustration below.)

Chart symbols of report points and control areas.

Points along the airways at which aircraft in flight *may report* their position to radio communication systems are indicated by a triangular marking (△); such points *at which reports are compulsory* are indicated by a solid color, triangular symbol (▲).

Moreover, an aeronautical chart indicates by blue tint all areas where air traffic is controlled. The rules for such control are explained in Chapter 6.

In view of the fact that omni-directional ranges reveal to the pilot the directions (magnetic bearing) of his aircraft from omni-range stations, a pilot can easily find his position in relation to the airport he wishes to reach. (See page 32). Such a circumstance might appear to lessen the need for designated airways. This is not the case. In order to prevent air traffic conflicts, scheduled air traffic must be controlled. This can be done only by means of the electronic facilities of airways and airports. The following chapters discuss some of the scientific principles upon which these facilities are based, briefly describe the operation of them, and outline the traffic rule enforced by means of them.

PROHIBITED AREA

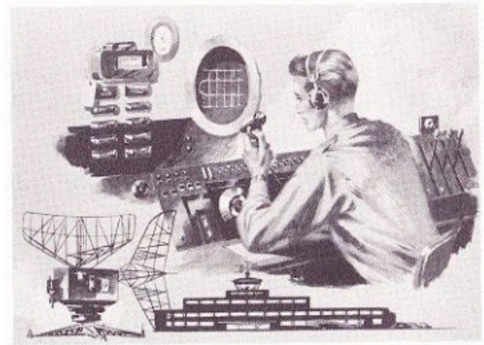
Flight of aircraft prohibited except by specific authority of using agency.

DANGER, RESTRICTED OR WARNING AREA

Invisible hazards to air navigation.

CAUTION AREA

Visible hazards to air navigation.



CHAPTER THREE

ELECTRONICS IN AVIATION

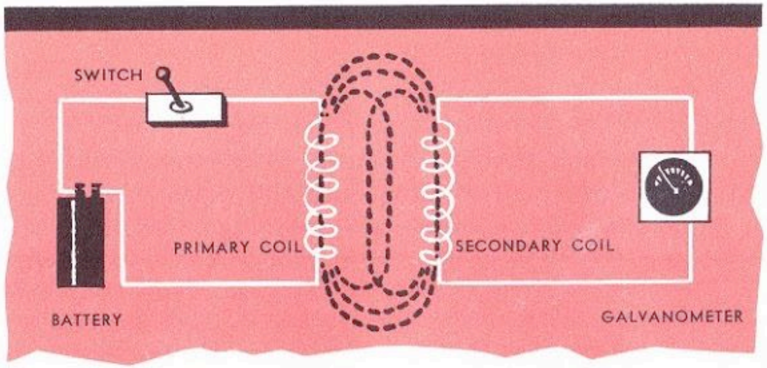
The radio in modern aviation.

The principles of radio make modern aviation possible. Radio signals mark the airways. By means of radio, airplane pilots are given take-off and landing instructions. Wherever aircraft fly, radio provides a means of ground-to-air and air-to-ground communication. Flight plans are filed, weather information is dispersed, and traffic is controlled—all by means of radio. Radio signals help the pilot keep the proper course, and radio, radar, and instruments which make use of radio signals guide him to safe landings, although clouds and fog may hide the airport and obscure his vision.

The basic principle of induction

The principles upon which radio is based are really quite simple. Electronic devices seem hard to understand chiefly because the things which make them work are invisible. We cannot see atoms and electrons; neither can we see electric currents nor radio waves. Yet, even if we cannot see them, we can get some ideas about them from the things they do which we can see, feel, or hear.

Through applying the principle of induction (see *Power for Aircraft,* page 30), a radio transmitter changes sound waves to audio waves. It then causes radio-frequency waves to carry the audio impulses (waves) through space, enabling a radio receiver tuned to the proper frequency to pick up the carrier wave and the audio impulses it carries, and to change these again into sound waves which you, the listener, may hear. Other electronic appliances make similar use of radio-frequency waves (electro-magnetic oscillations) which induce voltage within a secondary circuit.

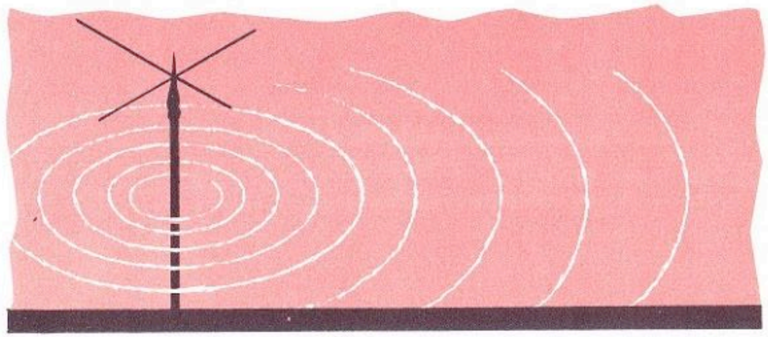


How electrical energy gets from transmitter to receiver.

You remember from your study of magnetos that to open and close a switch in the primary circuit would cause a magnetic field to build up and collapse around the primary coil of this circuit. The movement of the lines of force that occurred as a consequence, *induced voltage and alternating* movement of electrons within the secondary circuit. In the magneto, the primary and secondary coils were adjacent one to the other. However, the effect would have been the same had the coils been placed a considerable distance apart.

Magnetic lines of force.

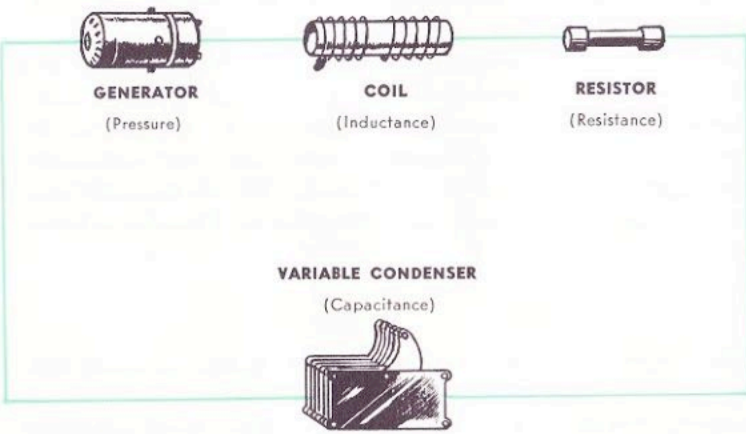
The magnetic lines of force around a bar magnet or a coil take a circular path from one of the poles of the magnet to the other. However, when the *flow of electrons* is through a linear conductor such as the antenna of a radio transmitter, the lines of force are circular and radiate outward in the form of waves, much as surface ripples move when a stone is dropped into a lake.



Controlling the nature of radio-frequency waves.

The electronic flow induced into a radio receiver has a very special task to perform; consequently, the primary circuit which transmits the radio-frequency waves modulated by the audio waves must be provided with some *special kinds of controlling* devices.

Among these devices are found resistors, induction coils, condensers, transformers, and electron tubes. Resistors offer resistance to the alternating flow of electrons in a circuit. (An electric light in a circuit is one kind of resistor.)



Inductance and capacitance.

The induction coil provides inductance in a circuit. Inductance is the property of a circuit that tends to oppose a change in the direction of an existing current. It is present only when the current is changing. The induction coil acts as a high-resistance resistor to an alternating current, as a low-resistance resistor to a direct current, and as a break in the circuit to very high frequencies.

The condenser provides capacitance in a circuit. Capacitance is the ability of a circuit to store up an electrical charge. In an electrical circuit, a condenser is composed of two sets of plates with a

non-conductor between them. Such a condenser may be of the fixed or variable type. The area of its plates determine the capacitance value of a condenser. The greater the capacitance of a circuit, the lower the frequency of its current's oscillations. Consequently, if the variable condenser of a circuit is turned so that it has a large plate area, the circuit will be tuned to a correspondingly low frequency; if it is turned so that it has a small plate area, the circuit will be tuned to a correspondingly high frequency. A condenser acts as a broken circuit to a direct current and as a low-resistance resistor to a low-frequency, alternating current. To a high-frequency, alternating current, the condenser appears to have no effect. *The frequency of the radio waves of a circuit is controlled by the relationship of inductance to capacitance.*

Transformers in the electronic circuit.

Important among the elements of electronic circuits are transformers and electron tubes. A transformer is a form of induction coil. You remember that the ratio between the number of turns of wire in a primary and the number in its secondary coil determines the change in voltage between the two coils. The function of transformers in the electronic circuit is to increase voltage.

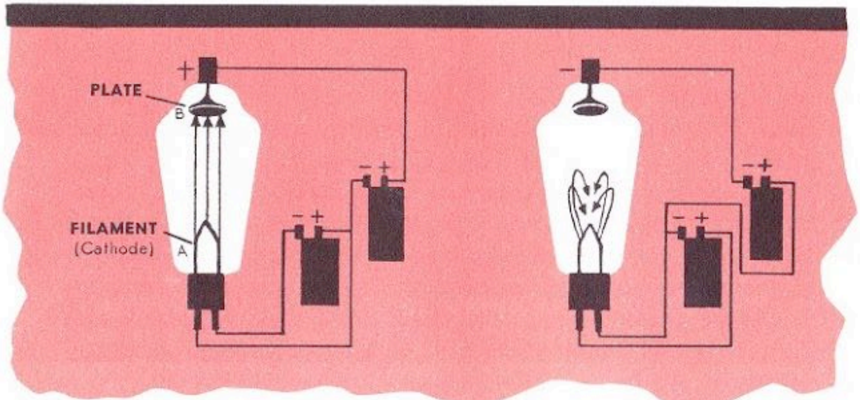
Electron tubes in the electronic circuit.

The scientific device which is perhaps the most important in modern radio communication and which has made possible many developments in electronic aids to aviation is the electron (or vacuum) tube. You know that radio was successfully used before electron tubes were invented, but without the electron tube, its use was quite limited.

The nature of the diode tube.

The fundamental principle of the electron tube is that the heating of a metal causes it to give off electrons. Electrons appear to escape from heated metal much as water molecules evaporate when water is heated. Edison in 1883 was the first to note the effect of electrons given off by a heated wire.

Following Edison's observation, an Englishman named Fleming discovered that if he placed a filament (a loop of very fine wire) and a



DIODE

metal plate within a vacuum tube, electrons would flow when the filament was heated and the plate was positive. He also discovered, when he made the plate negative, that although electrons still boiled off the heated filament they did not flow but gathered around the filament. (Unlike attracts, like repels.) Thus Fleming had found both a third method* by which electrons can be made to flow and also a method of changing alternating electrical currents to *direct electrical currents*.

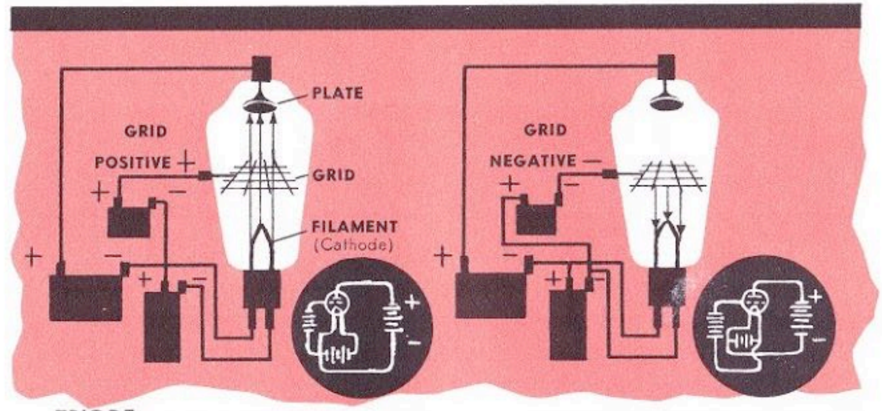
The nature of the triode electron tube.

In 1906, an American, Lee De Forest, added a third element to the vacuum tube. This element is called a grid. The three-element electron tube is called a triode. The development of the modern triode electron tube makes possible long distance radio transmission and many other electronic miracles. In the interest of refining the operation of the triode, other elements have been introduced into the vacuum tube: a four-element tube is called a *tetrode;* a five-element tube, a *pentrode*.

The grid.

The grid is a small coil of wire placed between the filament and the plate of the electron tube. When it is given a small positive charge, the flow of electrons from heated filament to plate is increased; consequently, the plate current is increased. When it is given a negative charge, the electrons will be repelled and remain

* The other two methods are induction (as in a generator, magneto, and induction coil) and chemical action as in an electric battery.



TRIODE

clustered around the filament; consequently, the plate current is decreased. These properties of the of the grid make it a control device.

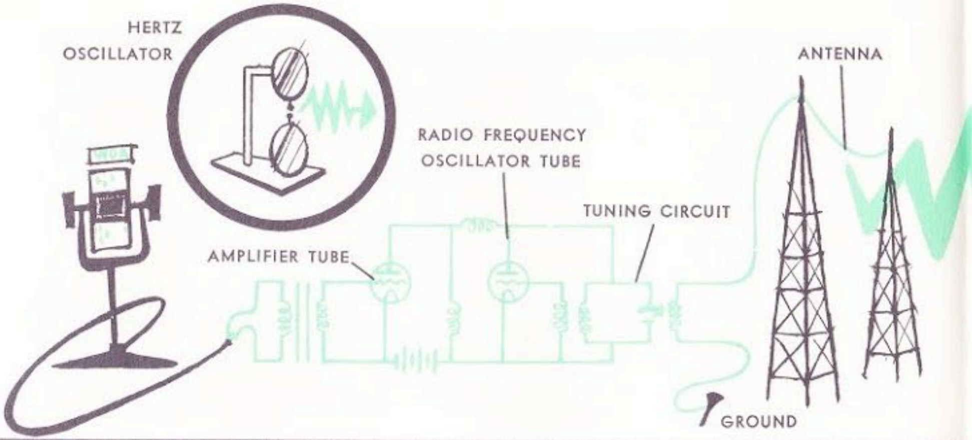
Why the grid can be used as a control of electron flow.

By regulating the positivity or negativity of the grid, the number of electrons entering the plate circuit can be controlled. A small change in voltage will cause a large change in the plate current. These properties of the grid make it a control device and enable the electron tube to perform its three most important functions in radio: oscillation, amplification and detection.

The stages of sound transmission.

In the first stage of sound transmission, sound waves strike the diaphragm of a microphone causing varying degrees of pressure upon carbon granules through which flows an electric current. The degree of flow of this current is directly proportional to the degree to which the granules are compressed. The more they are compressed, the more the current flow; the less they are compressed, the less the current flow.

It is this effect of the sound waves upon the microphone circuit that changes sound waves into audio waves. The voltage of the microphone circuit is now "stepped-up" by a transformer (see page 17) and fed into the grid circuit of the electron tubes.



In the second stage of sound transmission, the voltage variations of the microphone circuit, which correspond to the sound frequency (the audio wave) reaching the grid circuits of the oscillation tubes, cause variation in the amplitude of the radio-frequency wave (the carrier wave). These variations, obviously, correspond to the shape of the audio wave. Thus, electrical impulses representing sound waves are impressed upon the radio carrier waves. This process is called *modulation*. When the amplitude of the radio frequency wave is varied, the process is called amplitude modulation (AM.)*

Oscillation.

Heinrich Hertz (1889) developed the first device that would produce electro-magnetic waves that could be detected. This device called an oscillator consisted of an induction coil and a spark gap. When the induction coil was energized, the electrical energy would discharge across the gap. It was this discharge that could be detected. Radio frequencies are generated by electron tubes in much the same way that electric fluctuations were produced by the Hertz oscillator.

* Between 1935 and 1940, Major E. H. Armstrong devised a radio transmitting system which depends not upon amplitude changes, but upon frequency changes in the carrier wave. When the frequency of the radio wave is changed by the effect of the radio wave upon it, the process is called frequency modulation (FM). (See illustration page 21)

MODULATED RADIO FREQUENCY WAVE

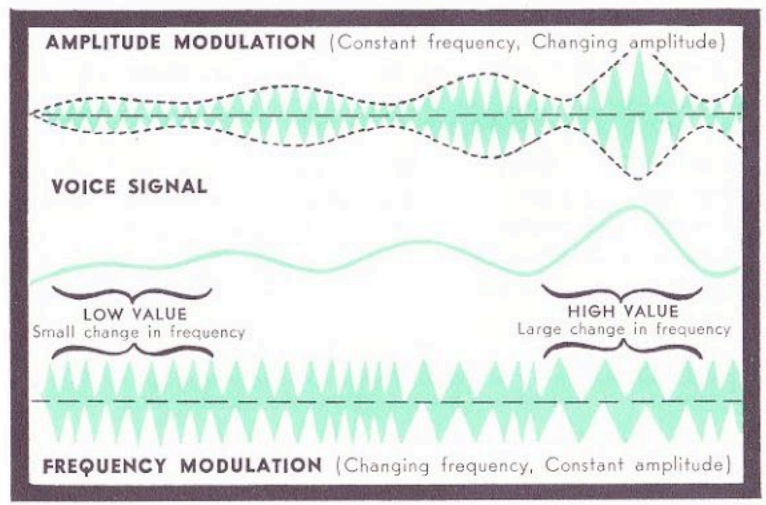
Amplification.

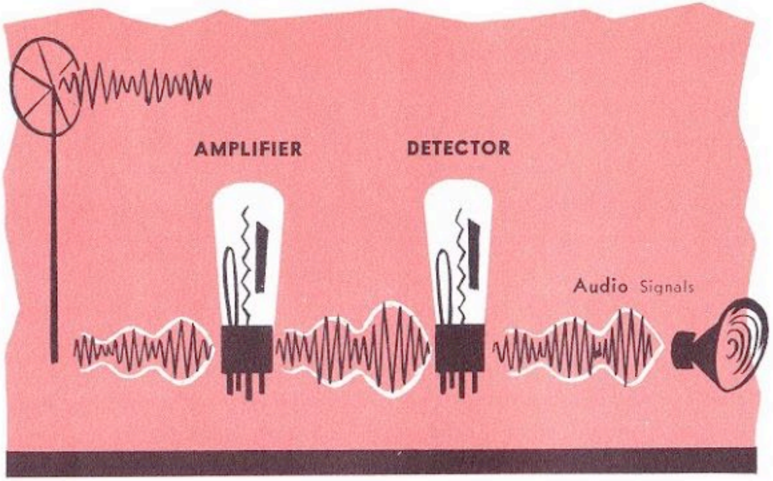
You remember that radio waves lose strength after they leave the transmitting station. Consequently, it is necessary that they be amplified by the radio receiver. This is accomplished by *connecting the receiving antenna to the grid of an electron tube known as the amplifier.* The alternations of the signals coming through the antenna will be amplified as the grid voltage of the amplifying tube affects the current of the plate circuit. This type of amplification is called *radio-frequency amplification.*

Detection.

When an electron tube is operated at a proper, negative, grid voltage, *vibrations are caused in its plate current corresponding to the audio wave* carried by the radio frequency waves. This process which separates the audio wave from the carrier wave is called demodulation.

After the radio frequency wave has been demodulated, the audio wave obtained is put into the grid circuits of audio amplifying tubes.





These tubes amplify the audio frequency waves just as the radio frequency amplifying tubes amplify the radio frequency waves. The diaphragm of loud speakers or pilots' headphones then convert the amplified audio waves into sound waves.

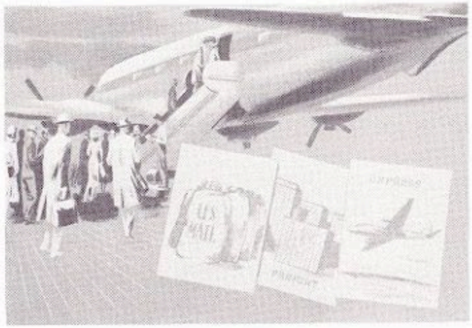
Electronics is a young and fast growing science.

Each day sees new electronic appliances developed and new industrial uses made of these. One school of thought is of the opinion that within a comparatively short period of time, aggressor nations will be deterred, not by fighter aircraft manned by pilots, but by electronically guided missiles that always reach their target.

Recently electronic research has made discoveries which are helping to improve electronic instruments now in use. For example, from a substance called germanium, very small devices called transistors can be made. When installed in an electronic circuit these will do much of the work previously done by the electron tube. From substances such as quartz and barium titanate, other small devices called *transducers* are made. These have made it possible to create an entirely new technological field—ultrasonics*. Should you in the future acquire a special interest in electronics, the study such an interest motivates will open for you the doors to a world of fascinating marvels.

---

* Ultrasonics finds many uses in industry. One of the most important of these is to drive the drills and cutters which shape brittle and hard-to-machine materials.



CHAPTER FOUR

WHY AIRPORTS ARE NECESSARY

The modern airport terminal building.

The departing airline passenger arriving at the airport of one of our larger cities finds much activity there. His airport limousine may be one of half dozen or more unloading passengers at one entrance while still other limousines and taxis load incoming passengers at another. An attendant takes his luggage and guides him to the proper airline counter, where a courteous and uniformed ticket agent verifies his reservations, checks his baggage, and places it on a conveyor which whisks it rapidly out of sight.

After receiving his "gate-pass" and information about the departure time of his flight and how to reach the proper aircraft, the passenger may look around him. He will be in the airport terminal building. That which he sees will have been arranged to accommodate him and other air travelers. He will find vending machines which sell a variety of things from hosiery to insurance. He can purchase his stamps from a vending machine, or at some airports he may patronize the Post Office which will be found within the building. In the most modern of airport terminal buildings, he will find a news stand, a book store, a drug store, a gift shop, a barber shop, a beauty shop, a snack bar, a restaurant, clothing stores for men and women, a cocktail lounge, and perhaps a club room. At any airport terminal building he will find ample waiting room and passenger accommodations.

The departing passenger will hear announcements of incoming and departing flights. If he looks out of the window onto the parking apron, he will observe these incoming and departing aircraft. Lines of passengers will be leaving, others will be boarding the aircraft which he sees. He will see luggage unloaded and loaded as planes discharge their passengers or are made ready for take-off. He will observe people fueling aircraft. He will see still other people performing still other tasks. Some of these tasks he may not understand. After his flight is announced, he surrenders his ticket or gate pass to an airline attendant and boards his plane. He is greeted by a smiling stewardess and departs the airport unaware of many airport activities designed to make his flight as safe as his departure was pleasant.

The airport's operations.

Some of these "behind-the-scenes" airport activities are called airport operations. These operations may be conducted by a commercial aviation business, such as a scheduled airline, a charter service, a flight school, or a maintenance and repair service based at the airport. Aviation businesses conducted at the airport, other than those of the airlines, are called *fixed base operations.*

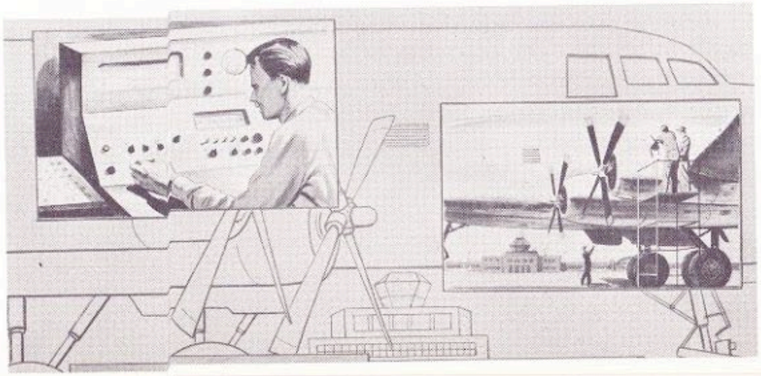
Airport administration.

Behind-the-scene, airport activities include the work of administering the business affairs of the airport itself. Many business details engage the attention of the airport administrator and his staff. These range from the collection of rentals from those who use the airport's facilities to the construction of airport buildings and runways.

Airline operations.

When the airline passenger requests a reservation, he is told either that space is available and that his reservation can be confirmed or that no space is immediately available and that if he chooses he may obtain a reservation on an alternate flight. Before flight information can be given to passengers, rather detailed and exact records must be kept by the telephone-sales section of the airline. Sometimes this service is located at the airport. When such is the case, like many other airline tasks which keep transport aircraft flying and passengers happy, it escapes notice. Generally, when the airline passenger thinks about the work of the airline, he thinks of the pilot and perhaps the mechanic. Yet, fewer than 10% of airline employees are pilots, and fewer than 25% are mechanics. (See *Aviation and You*, pp. 19-21.)

"Behind-the-scene" airport activities.



Government airport operations.

Behind-the-scene, airport activities include certain services provided to all types of aviation by the Federal Government; for aviation in the few short years of its existence has become very essential both to our national economy and to our national defense. Without the Federal Government services housed in airport buildings, modern air transportation could not exist. These services are made available by the Weather Bureau, by the Federal Aviation Agency (FAA), and at military air bases by the U. S. Air Force and Naval air operations. They range from the briefing of pilots planning a cross-country flight to the installing and operating of radio-range stations and approach control and aircraft landing systems.

The pilot and flight assistance service.

Imagine that you are a pilot planning a flight to a distant airport. Under such a circumstance you will need to know certain things. First of all, you will need to know about the weather.

Will it offer any obstacles to your flight, requiring you to fly a longer route or to use special flight instruments en route? Then, you will want to know what radio facilities along your route are operating; what runway conditions you may expect at your destination, and what service facilities are available at the airport of your destination. *Flight assistance service* will give you answers to all these questions and even help you prepare and file your flight plan.

The radio and flight assistance service.

Once you are en route, you may still use the flight assistance service, if your airplane is equipped with a radio in operating condition. Twice each hour, at 15 and 45 minutes past the hour, weather reports are broadcast whether you ask for them or not. You may, however, use your radio to ask for weather information at other times. You may also request other information, such as help in establishing your position, the condition of radio aids along your route, and the general conditions at the field where you are to land. It is best not to call for information too near the time of the regular weather report broadcasts. But at all times, flight assistance is no further from you as a pilot than is your radio transmitter-receiver.

Air Traffic Control (ATC).

Air Traffic Control facilities are located at major airports. One of these is the airport traffic control tower. The other is the air route traffic control center.

Airport traffic control towers are often provided with approach control facilities for instrument landings. They are designed so that on clear days nothing obstructs the control tower operator's view of the airport or the sky above it. Approach control radar provides the controller with a means of observing the position of aircraft when clouds cover the sky. Consequently, the men or women working in the control tower are able to tell the pilot when, without fear of colliding with other aircraft, he can taxi into take-off position, take-off, land, and after landing, taxi to the ramp or hangar.

Approach Control.

On days when the weather is such that visibility is obstructed, Approach Control is operated by the control tower. Approach Control may use several different kinds of radio and other electronic devices. Each of these serves a specific purpose and is used in coordination one with the other to help the pilot land safely.

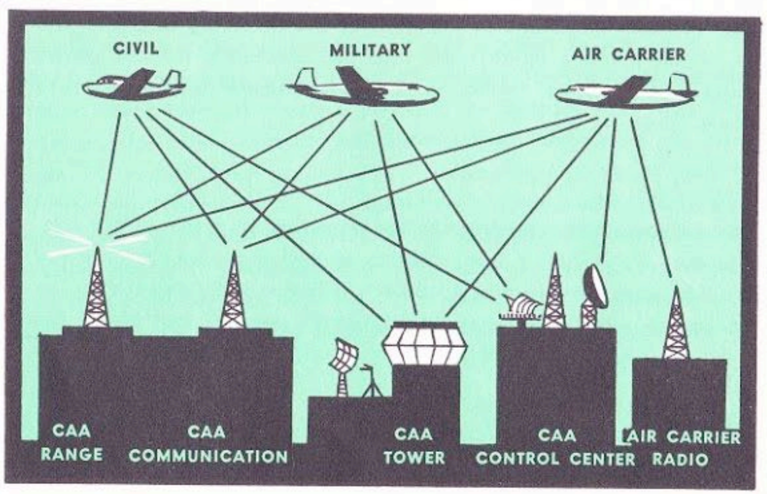
Airport Surveillance Radar (ASR) is an electronic device used by Approach Control to learn the bearing (direction) and distance from the airport of the incoming aircraft before it begins its "let-down" approach. This information is given to the pilot by radio. Precision approach radar (PAR) is an electronic device that shows to the PAR operator in the tower the position of an incoming airplane on its glide path. By the use of radio, the operator on the ground gives proper landing directions to the pilot of the incoming aircraft. The pilot of the landing aircraft will also use electronic devices called localizer, glide slope facility, and ILS (instrument landing system) markers. (See p. 35.)

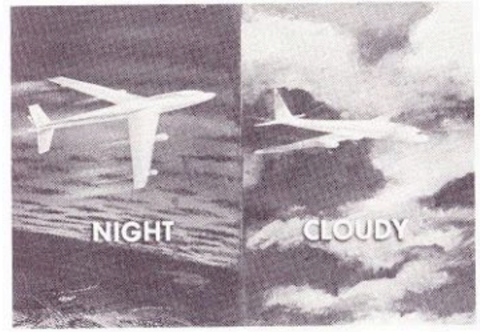
Air route traffic control centers.

The air route traffic control centers supervise air traffic within control areas. The control area proper is a designated civil airway which has necessary control facilities. It is generally defined as an airspace ten miles wide extending upward from 700 feet above the surface. However, control areas may be expanded to include areas near airports not on the airways over which aircraft fly on IFR (instrument flight rules). The control facilities administered by air route traffic control centers, like the facilities of communication stations and the airport traffic control tower and its approach control, employ electronic devices adapted to special purposes.

Airline facilities supplement government operations.

Airline communication services, which supplement some of the Federal Government services, may be found at many airports. Every effort is made by both industry and government to make flying safe and to provide for the growth and development of aviation. Just as the FAA and the Weather Bureau in the interest of aviation safety use both electronic and land-line communication systems, the airlines also use such systems. The airport is the center from which radiate all of these services, whether provided by government or industry. The fact that the airport is an aviation administration center employing many devices based upon the discoveries of modern science may escape the attention of the casual visitor and the airline passenger. Yet, these activities are most significant. The airport, whatever its size and whatever activities are found there, has as its primary purpose to provide a take-off and landing area for aircraft. Yet, were it not also used as a center from which services, in the interest of safe take-off, safe flight, and safe landing, are available, civil and military aviation as we know it would not exist; there would be little incentive for practical aviation pursuits; and our national defense and economy would suffer.





CHAPTER FIVE

AIRWAYS

and the facilities of air traffic control

All-weather flight.

If aircraft could fly safely only when the pilot could see the ground below him and other aircraft in the sky around him, airways and the methods used to control the traffic along them would be comparatively unimportant to aviation operations. However, the pilot of an airplane must be prepared to guide his aircraft when he can see nothing ahead of him nor below him except cloud or fog.

Under these and similar conditions, he must avoid other aircraft in flight and keep a safe distance from mountains, radio towers, and other such obstructions. He must also fly directly to his destination, know when to begin his descent so that he can reach the airport runway, and complete his landing safely. Radio and electronic aids make these things possible.

Radio aids and electronic devices.

Radio aids have helped make flying safe since they were first introduced in aviation. You have learned, however, that the increase in number of modern aircraft in operation has made it necessary to adopt improved radio devices. (See page 6.) Although older radio aids are still used, modern aircraft make increasing use of modern electronic devices. Such devices are installed and maintained by the FAA, Office of Air Navigation.

Air-ground communications.

As a matter of fact, air-ground communication made possible by the two-way radio is indispensable to modern aviation. By means of radio the pilot may, through the communication stations along his route, ask for and receive instructions from traffic control centers and from weather service. Aircraft radios which have been put into most recent use, operate on frequencies between 108 and 150

megacycles (very high frequency). Some military radio communication facilities operate on frequencies above 200 megacycles.

Radio ranges and airways.

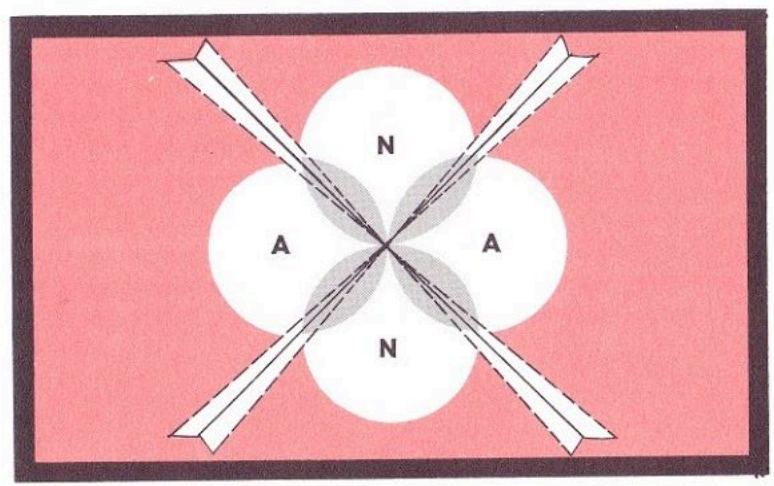
Radio ranges, you remember, actually tell the pilot where the airway is located. The low frequency, range station transmits signals in such a way that overlapping of signals defines four courses. The high frequency, range station transmits signals in such a way that, no matter what the flight position of an aircraft is, the pilot can always tune in on a direct course to the station near his destination.

The low frequency, range station.

The low frequency, range station (LF/MF) has one advantage over the high frequency, omni-range station (VOR) which will likely keep many LF/MF range stations operating for many years to come. Low frequency broadcasts can be tuned in at low altitudes and can be received on the ground. High frequency broadcasts like television broadcasts follow a "line-of-sight" direction. The curvature of the earth obstructs VOR signal reception by aircraft flying at low altitudes.

LF/MF radio range signals are broadcast on frequencies from 200 to 415 kilocycles. Each range station is assigned a three-letter identification signal which is transmitted at 30 second intervals. Weather information is also broadcast by these stations.

Through the use of special antennas the Morse code for A (- —, dit da) is directionally broadcast into two opposing quadrants of



The four-course radio range.

the range and the Morse code for N (— -, da dit) is broadcast into the other two quadrants. These signals are of equal amplitude and interlock along the quadrant boundaries to make a steady tone which defines the course. This tone is continuous except when broken to accommodate station identification signals and weather reports. In order to receive the signals transmitted by these stations, the radio receiver must be tuned to the proper frequency. This frequency can be found by referring to the appropriate aeronautical chart. (See page 11.)

As the distance from an LF/MF radio range station increases, the beam it transmits fans out and its signal begins to fade. However, as the distance from the range decreases, its beam narrows and its signal becomes stronger. Directly over a station is a cone of silence. An aircraft entering a cone of silence will receive no course signals. Voice broadcasts, however, will still be received.

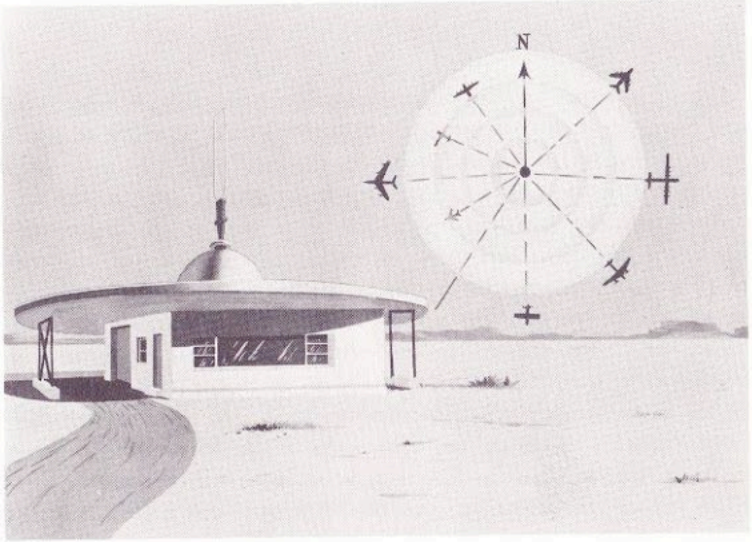
The very high frequency, omni-range station.

The omni-range station (VOR) sends out two signals in the 108-118 megacycle radio-frequency band. One of these, from the center antenna of the five antenna group, is non-directional. It radiates in the form of a circle expanding and contracting exactly 30 times each second. The second signal, from the four corner antennas, forms a figure eight pattern that rotates clockwise 30 times each second with the center antenna as its center of rotation. The first signal is called the *reference-phase signal;* the second, the *variable-phase signal.*

The VOR range is set so that the variable-phase signal pattern points toward magnetic north at the exact time the reference-phase signal reaches its maximum expansion. At this time, on a line (or radial) extending between the VOR and magnetic north, the two signals are in phase (match) with each other. All other radials (lines extending from VOR) are in different phase. The VOR receiver is able to measure the degree of this difference and indicates it on the dial of a *visual indicator* on the aircraft instrument panel.

The basic idea underlying VOR.

So that you can better understand how VOR works, let us compare it with a special kind of airport beacon which does not actually



Very high frequency omni-range.

exist. However, suppose a fixed, green, beacon light flashed every time that the rotating light beam of this imaginary beacon sweeps past magnetic north. Assume that the beam rotated once each 10 seconds. In that event, since there are 360° in a circle, it will pass through 36° each second $\left(\frac{360°}{10}\right)$ It is possible for a pilot to find his direction from this beacon (1) by starting a stop watch upon seeing the green light and stopping it when the beam sweeps past him and (2) by then multiplying the number of seconds shown on the stop watch by 36°. If the pilot's stop-watch shows 7.5 seconds, his position with reference to the beacon will be 270°. That is, he will be directly west of the beacon. *The VOR receiver is a kind of combination stop-watch and calculating machine which uses radio signals rather than light signals as a basis for its computations.*

The radio marker beacon: a supplement to the range station.

Although the radio range stations tell a pilot of an aircraft in flight where the airways are located and the direction of airport from his aircraft, they give him no information as to his distance from the airport.

He must depend for this information upon his skill in navigation and the knowledge he has of the direction and strength of winds which may affect his speed over the ground. Or, if his aircraft is properly equipped, he may use electronic devices called markers.

There are two principal types of markers used for this purpose—fan and Z markers. Both types of markers operate on the frequency of 75 megacycles. The fan marker is 3 miles wide and 12 miles long across the airway near the earth's surface. However, at higher altitudes, the signals spread out until their effect covers a correspondingly greater area. The Z marker is always located at the site of an LF/MF radio-range station. It radiates a cone shaped signal vertically above the range station. (See page 32.) If the marker receiver of the aircraft is tuned to 75 megacycles, the pilot receives a signal when his aircraft flies over a marker. He will hear a tone, and the marker light will glow.

Flight position.

The pilot who uses a VOR receiver can use this to find his position along his route. He knows the bearing he is flying. He can tune his receiver to another VOR station to the right or left of his course and take a bearing on this VOR station. If he plots the two bearing lines on an aeronautical chart, they will intersect. (See illustration page 9.) The point at which they intersect is his chart position. From this and other chart information the distance of the aircraft's position from the first VOR station may be found.

The DME.

Within the last few years an electronic speedometer for aircraft has been developed. This device is called Distance Measuring Equipment (DME). In the cockpit of an aircraft using DME, the pilot can learn from an indicator his distance to or from a VOR station.

DME requires receiver-transmitter combinations on both ground and in the aircraft. It operates at 1,000 megacycles. The ground equipment is called a *Transponder;* the airborne equipment is called an *Interrogator*. DME equipment is very intricate. When one thinks of the speed at which ultra-high frequency radio waves travel (approximately at the speed of light—186,000 miles per second) it seems incredible that DME can measure the time required for the radio impulse to travel a few miles; *yet it is able to do this task.*

VORTAC.

When TACAN (tactical air navigation) is combined with VOR, the installation is termed a VORTAC system. TACAN is an air navigation system developed by the military services. The VOR feature of VORTAC will provide directional information to civil aircraft. The TACAN feature will provide directional information to military aircraft and distance information to both civil and military aircraft. Eventually the TACAN feature of VORTAC stations will replace DME facilities.

The Course Line Computer.

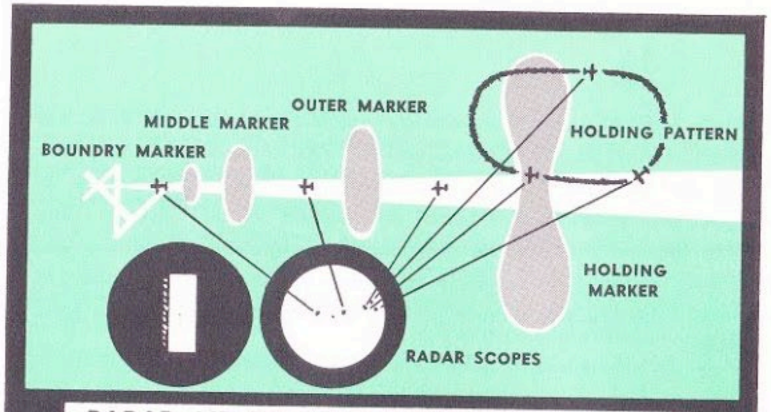
Should a pilot wish to fly his aircraft on a path that does not pass directly over a VOR or VORTAC station, he can still make use of the station. The device that makes this possible is called the *Course Line Computer.*

The *Course Line Computer* by means of information fed to it electronically by VOR ground equipment actually solves a pilot's navigational problems. The pilot simply sets the proper information into the computer, then flies the needle (heads the aircraft so that the indicator needle is properly centered) to his destination. For all practical purposes, he has apparently moved the VOR station from its location to the point of his destination. One type of course line computer, called a pictorial computer, shows the pilot his position and progress by means of an indicator which moves across a chart as the aircraft moves through the air.

Other electronic instruments.

If low-visibility weather conditions prevail at the time an incoming flight reaches an airport, other electronic equipment the aircraft carries may be put into use. Localizers, glide slope indicators, and marker detectors receive and interpret signals from ground installations. (See page 27.) The localizer gives the pilot of an incoming aircraft lateral (sideways) guidance during his landing approach. The glide slope indicator gives him vertical (up and down) guidance. The Instrument Landing System (ILS) markers tell him how far he is from the airport.

The airways modernization program of the Federal Aviation Agency in its efforts to facilitate airway traffic control within high density control areas has sponsored the development of navigation systems contained within the aircraft itself and which do not depend completely upon ground-controlled facilities. Such systems are typified by HIDAN (High Density Air Navigation) manufactured



RADAR AID TO AIRPORT TRAFFIC CONTROL

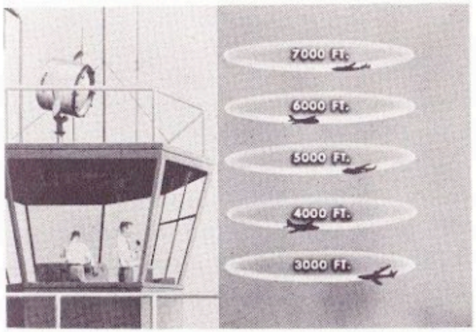
by General Precision Equipment Corporation. HIDAN consists of an airborne automatic navigation component which reports continuous ground speed and drift angle and a position component which instantaneously indicates divergence of the aircraft from its planned position along its flight course.

Electronic devices: versatile servants of aviation.

The devices that help airports and airways do their most important tasks and help the pilots guide their aircraft safely, all are based upon the science of electronics. Electronic devices mark the thousands of miles of airways that cover continental United States. They make possible the control of the traffic along these airways. They make possible landing and take-off operations at airports during low-visibility weather conditions.

You may follow, as a career, fields of interest other than aviation or electronics. In that event, the general understandings of electronic circuits which you now have gained is sufficient. You have learned about principles which are basic to the tools men use to prevent air traffic conflicts and keep air travel safe.

Should you choose to follow a career in aviation electronics, you will need to learn in detail how each of the devices based upon the electronic circuit operates. Someday, you may need to learn how to operate or repair these and other electronic devices that are now in process of development. When that time comes, the understanding of the basic electronic principles which you have gained from your present studies will be of great help to you.



CHAPTER SIX

THE REGULATION OF AIR TRAFFIC, I

The need for air traffic control.

Since air space is three-dimensional, it would almost appear that the regulation of air-traffic is unnecessary. Unlike the automobile whose travel route is a roadway, the aircraft in transit need not rely upon a narrow path. Moreover, aircraft in flight have an advantage over the automobile in highway traffic, in that one aircraft may pass around, over, or under another. However, there are certain things an automobile on the highway can do that an airplane in flight cannot do. An automobile can stop at an intersection signal, permitting a flow of cross-traffic. Since an aircraft to stay aloft must keep in continuous motion, there can be no accommodating pauses in the flow of air traffic. Moreover, during instrument flight conditions (when clouds or other obstructions to vision prevail) the advantages of three dimensional travel actually become hazards. For, if one aircraft were permitted to fly at any altitude and along any course, unrestricted and uncontrolled, *another* aircraft would have the same privilege, and collision between the two during low-visibility weather conditions would become likely.

The purpose of air traffic regulation.

Air traffic regulation is important in the interest of safe operation of aircraft. In addition, it is essential to modern aircraft operation because the flow of air traffic in and out of modern airports is so heavy that without it, maximum use cannot be made of airports and airways, and serious traffic conflicts will occur.

The facilities of communication.

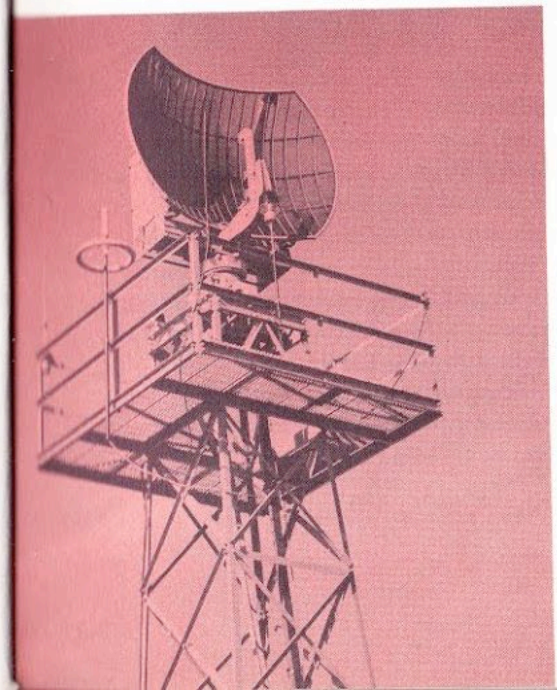
Both radio signals and light signals are used to convey air traffic information from ground communicators to the aircraft flight crew. Chapters IV and V offer general explanations of the devices and appliances of radio and the uses of some of these in communications. When you study the operational procedures of radio, you will learn in detail how to use radio communications in aviation. Before you

learn this procedure, however, it is necessary to learn in a general way the purposes for which the procedure has been established. It also should be remembered that some light aircraft may be equipped only with the essential instruments for clear weather flying. Consequently, these aircraft will have no radio transmitter nor receiver. Under such a circumstance, light signals, each of which has a specific meaning understood by pilot and communicator are directed toward the maneuvering aircraft by means of a "light gun" which shoots either a red, green, amber, or white beam.

The scope of air traffic regulation.

Air traffic, both at airports and along airways, is governed by regulations. At the airport, the movement both of aircraft on the ground and of those departing and arriving is in accordance with established rules. Along the airways, the movement of aircraft also must be in accordance with prescribed procedures. Moreover, regulations formulated in the interest of the safe and expeditious flow of air traffic are concerned not only with air traffic rules but also, under certain flight conditions, with proper aircraft equipment and special pilot skills.

The methods of flight regulation and control.



Air traffic regulation employs a system founded upon three things:

a. A body of regulations, based upon analyses of practical flight situations, prepared by the Federal Aviation Agency.

b. Services which use electronic and other communication facilities by means of which pilots of aircraft receive advice, instruction, and flight information.

c. The pilot's good

judgment and his use of good operating practices.

Flight paths and airspace.

An aircraft's position in the air space above a certain kind of surface area governs the air traffic rules under which it operates. For example, when an aircraft is flying over or near an airport, it is governed by rules that may not apply when it is flying along an airway.

Control zones and control areas.

For the sake of convenience, traffic regulations are classified in terms of control zones, control areas, and elsewhere. A control zone is an air space extending upward from the surface of the earth. Its dimensions have been established by the FAA Administrator. It includes at least one airport and the air space over land adjacent to the airport.

A control area is an air space extending upward from an altitude 700 feet above the surface of the earth. It generally includes the air space used by aircraft flying along civil airways. You remember that although a civil airway is a path through air space which can be navigated and which the FAA Administrator has approved as suitable for air commerce, it is not necessarily within a control area. It is only within a control area when it has facilities, such as air-to-ground radio communications, radio-range stations and marker beacons, which make traffic control possible.

On December 1, 1957, the Federal Government instituted a Continental Control Area including airspace within continental United States at and above 24,000 feet. Within this area FAA control is optional with the pilot during clear weather but compulsory during periods when visibility is less than 5 miles. Aircraft operating within this area VFR may not fly nearer a cloud formation than 1,000 feet vertically nor one mile horizontally. Series of routes for jet aircraft operating at high altitudes were also desingated, and on June 15, 1958, three new transcontinental routes linking New York and Washington, D. C., with Los Angeles and San Francisco were inaugurated. These routes are 40 miles wide, begin at an altitude of 17,000 feet,

and extend to an altitude of 22,000 feet. Civil and military aircraft must file IFR flight plans (see p. 49) before either type is permitted to use these routes. Also, in the interest of avoiding traffic conflicts, air carrier companies have voluntarily agreed to file IFR flight plans, regardless of weather conditions, before operating above 10,000 feet along any air route.

The control area extension.

Sometimes aircraft arriving at an airport during low-visibility weather conditions cannot be cleared for an immediate landing. The pilot in such instances is instructed to hold (fly a circular course at a designated altitude). Since flight during the time an aircraft awaits landing instructions must also be controlled, the air space within which this kind of maneuvering takes place is called a control area extension.

As a matter of fact, certain flight regulations establish some controls over flight elsewhere than in control areas and control zones. The difference between the types of control exercised in control zones and areas and that exercised elsewhere, results chiefly from differences in the amount of air traffic. For, where air traffic is sufficiently heavy so that hazards to safe flight operation threaten, control areas are extended and facilities for air traffic control are soon established.

Airport VFR traffic and taxi procedures. (VFR is the symbol which stands for Visual Flight Rules.)

At airports which have control towers in operation, airport traffic control is exercised by such towers during VFR weather conditions. At such airports all movement of aircraft within the airport's control zone must be cleared either to taxi, to take off, or to land. Clearance in these instances may be communicated to the pilot of an aircraft by means of either radio or light signals.

When his aircraft is equipped with an aircraft radio, the pilot simply tunes to the proper channel[1] and asks instructions. He receives these by tuning his radio receiver to the proper channel[2] and operates his aircraft accordingly.

Light signals and their meaning.

When his aircraft is not equipped with radio, the pilot depends on light signals for his information. The following chart lists these signals and gives their meanings:

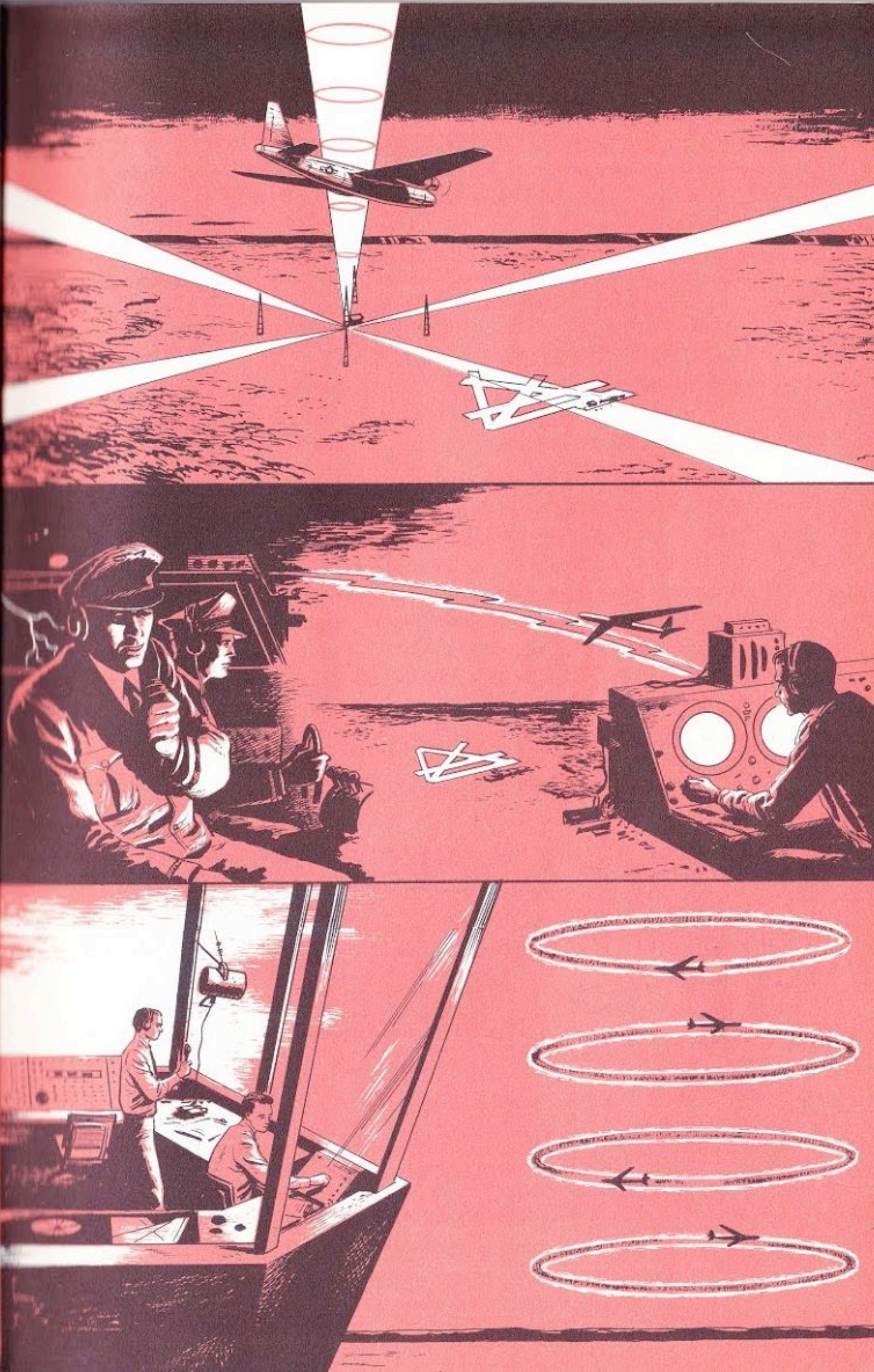
Signals from a portable, traffic control light and their meanings

Color and Type of Signal	On the Ground	In Flight
STEADY GREEN	Cleared for take-off	Cleared to land
FLASHING GREEN	Cleared to taxi	Return for landing (to be followed by steady green at proper time)
STEADY RED	Stop	Give way to other aircraft and continue circling
FLASHING RED	Taxi clear of landing area (runway) in use	Airport unsafe—do not land
FLASHING WHITE	Return to starting point on airport	. . . .
ALTERNATING RED AND GREEN	General Warning Signal — Exercise Extreme Caution.	

Pilots should acknowledge light signals during hours of daylight by rocking the wings of their aircraft in flight and during hours of darkness by blinking their landing or navigation lights. At night in order to attract the attention of the control tower, the pilot of an

[1] Radio transmitters used on light, private aircraft have fixed reception positions. Those used on commercial aircraft may have several positions; the pilot selects the one appropriate, such as you select a channel on your television set.

[2] Taxi information is communicated on frequencies of 121.7 and 121.9 mc. Air Traffic Control communications use frequencies in the 118.1 through the 121.3 mc range and 123.7 through the 126.5 mc range. Frequencies used by airport and airway radio facilities may be found on the aeronautical charts.

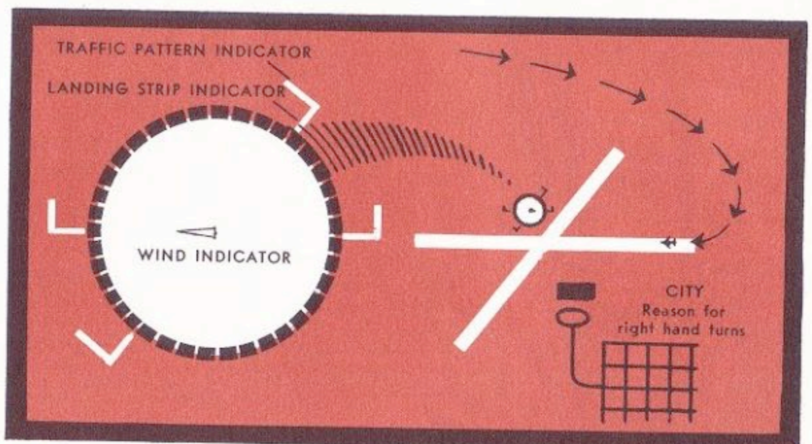


aircraft not equipped with radio should turn on his landing lights and taxi into a position which makes these visible to the tower operator.

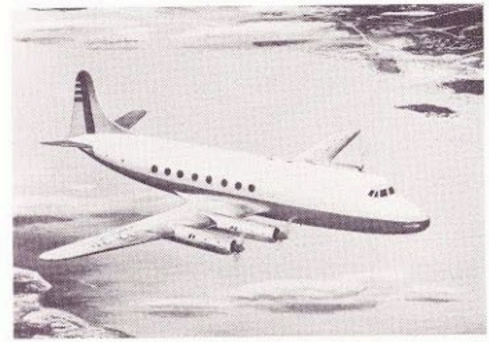
If the rotating beacon of an airport is lighted during hours of daylight, it means that weather conditions are below VFR minimums and that an Air Traffic Control clearance is necessary for aircraft operation. During the hours of darkness, flashing lights outlining the traffic direction indicator (wind tee, tetrahedron, or other such device) has the same meaning.

Airport traffic patterns.

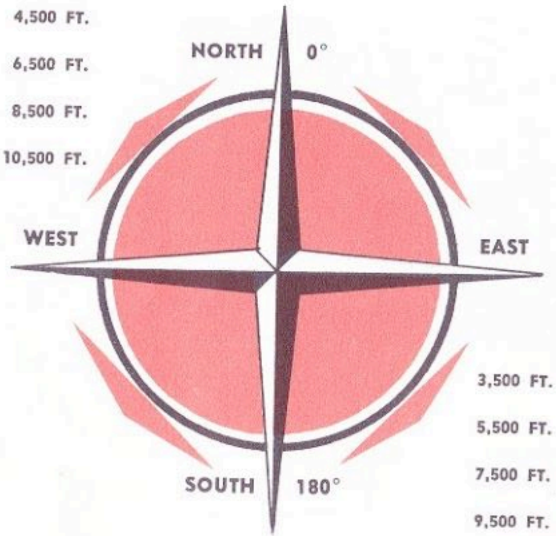
An aircraft not equipped with radio, upon arriving at its destination, makes at least one complete circle of the airport, conforming meanwhile to the proper traffic pattern and watching both for other aircraft and for a signal from the control tower. At some airports, a segmented circle is used to convey traffic pattern information (See illustration page 44). A pilot should observe the flow of traffic to determine the runway in use and, in the absence of traffic, use the runway which will enable him to land his aircraft into the wind. A wind tee, tetrahedron, or other wind indicator will give him the wind direction. Upon its final landing approach, a pilot, when practicable, should keep his aircraft on a straight course for the last 1,000 feet before crossing an airport boundary.



Segmented Circle



CHAPTER SEVEN



The VFR odd-even altitude rule.

THE REGULATION OF AIR TRAFFIC, II

The flight rules.

The rules under which an aircraft operates depend in part upon the weather which prevails. If the rules followed are those practiced when the weather is comparatively clear, it is customary to say that the flight is a VFR flight. If the weather is such that the cloud ceiling is quite low and flight visibility is obstructed, aircraft operating legally will be governed by IFR (Instrument Flight Rules) procedures.

Visual flight rules.

The flight of an aircraft operating on VFR procedures is restricted by the location of an aircraft's operation and the weather conditions at the time of its flight. To help you understand the relationship between the location of a flight and the corresponding VFR procedure, the following table is used:

Ceiling, Visibility and Cloud Clearances; VFR Minimums

		In Control Zones	In Control Areas	Elsewhere
At altitudes over 700' above the surface	Visibility	3 Miles[1]	3 Miles	1 Mile
	Distances from clouds	500' under 1000' over 2000' horizontally 1000' ceiling	500' under 1000' over 2000' horizontally	500' under 1000' over 2000' horizontally
At altitudes at or under 700' above the surface	Visibility	3 Miles	1 Mile[2]	
	Distances from clouds	500' under 1000' over 2000' horizontally 1000' ceiling	Clear of clouds	

"On the top flight" (the operation of aircraft above a well-defined cloud formation) may be undertaken by aircraft operating VFR, provided that the climb to and descent from such flight can be made in accordance with visual flight rules. Under such circumstances, the required horizontal, visibility distance is still three miles. Moreover, as he climbs to or descended from his cruising altitude, the pilot must still keep a horizontal separation of 2,000 feet between his aircraft and the cloud formation.

VFR altitude rules.

You remember from the chapter on Aeronautical Charts (see page 11) that airways are identified as either colored or Victor airways depending upon whether the ranges which define them are four-course or omni-directional. Green, red, and even numbered Victor

[1] When visibility conditions are below minimum, if IFR traffic conditions permit, authorization to conduct local VFR operations, such as practice take offs and landings, may be given by ATC (Air Traffic Control) to an airport operator.
[2] Helicopter operation at reduced speeds is not governed by this minimum.

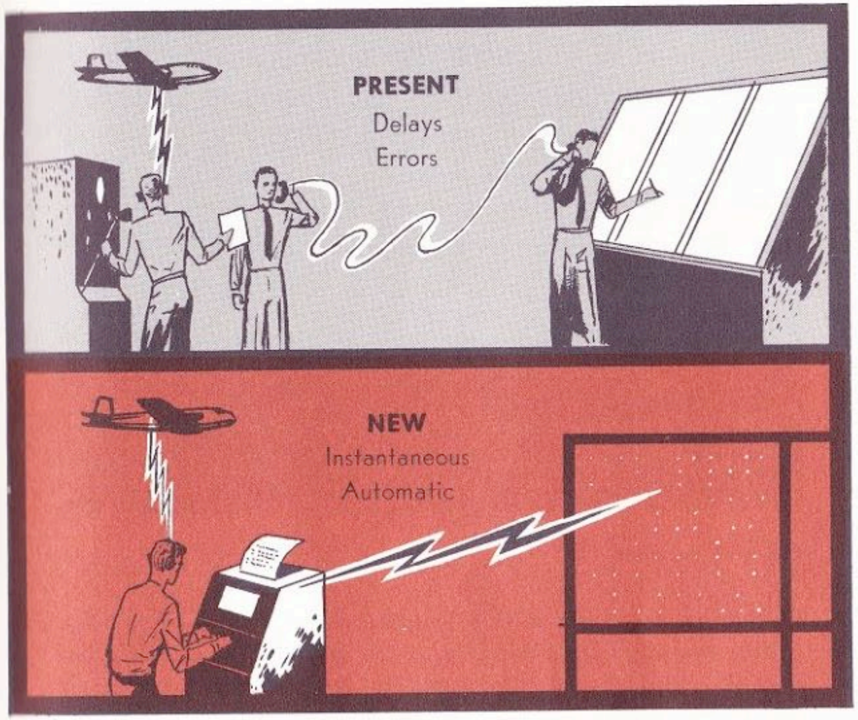
airways are east-west airways. When aircraft are flown on magnetic courses between 0° and 179° upon such airways at an altitude of or over 3,500 feet above the surface, they must maintain an indicated altitude above sea level which is at the "odd-thousand-plus-500-foot levels," such as 3,500 feet, 5,500 feet, 7,500 feet, 9,500 feet, etc. When aircraft are flown between 180° and 359°, they must maintain an indicated altitude which is at the "even-thousand-plus-500-foot levels," such as 4,500 feet, 6,500 feet, 8,500 feet, 10,500 feet, etc.

Amber, blue, and odd-numbered Victor airways are north-south airways. Along these airways, aircraft operating between 0° and 179° and at levels of 3,000 feet or over are flown at odd-thousand-plus-500-foot altitudes. Aircraft operating between 180° and 359° under like conditions are flown at even-thousand-plus-500-foot altitudes. Aircraft more than 3,000 feet above the surface within a control zone are also governed by the odd-even flight altitude rule.

When in level cruising flight, the flight-path altitudes of aircraft operating elsewhere than within a control zone or area and flown at 3,000 feet or over 3,000 feet and under 29,000 feet above the surface are governed by the magnetic course the aircraft follows. Aircraft on magnetic courses between 0° and 179° cruise at odd-thousand-foot levels plus 500 feet (3,500′; 5,500′; 7,500′; etc.); between 180° and 359°, at even-thousand-foot levels plus 500 feet (4,500′; 6,500′; 8,500′; etc.) The flight-path altitudes of aircraft flown above 29,000 feet are separated vertically by 4,000-foot intervals. For flights on magnetic courses between 0° and 179° such separations begin at 30,000 feet; for flights on magnetic courses between 180° and 359° such separations begin at 32,000 feet.

Instrument flight rules.

Flight plans may be filed for aircraft operating VFR. In fact, it is a safe practice always to file a flight plan. It is required that flight plans be submitted for aircraft operating when weather conditions are below VFR minimums. The filing of an instrument flight plan assures Air Traffic Control that the aircraft is equipped for instrument flight and that the pilot holds instrument ratings. Before leaving or entering a control zone or area, aircraft operating IFR must submit a flight plan and receive an air traffic clearance.

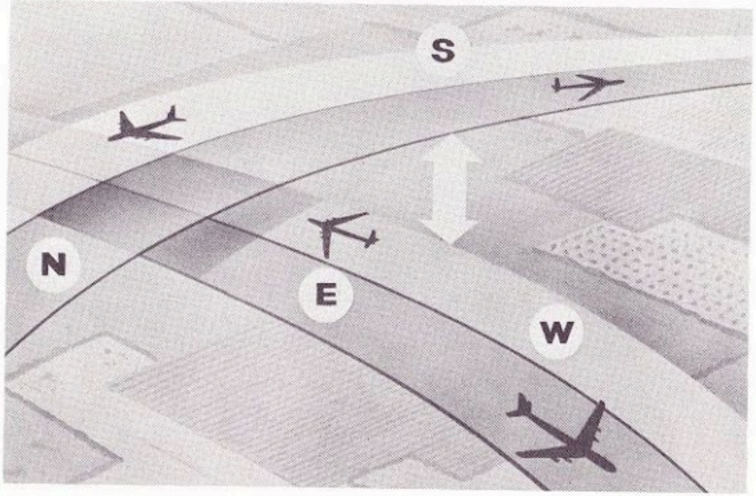


Air Traffic Control Communications

The flight plan.

The flight plan may be filed with the nearest airway communication station, airport traffic control tower, or air-route traffic control center by person, telephone, or radio. It is by means of information given on the flight plan that the air traffic controller can *plot* a flight accurately *and plan* the flight's movement in terms of the prevailing flow of air traffic. The flight plan contains information about the type and identification of the aircraft and the name, address, and certificate number of the pilot in command. In addition to the airport of intended destination, the flight plan names alternate airports within the aircraft's radius of flight. The flight plan also states in terms of hours and minutes the amount of fuel on board.

Of special significance to Air Traffic Control are the following items which the flight plan must contain: the point of departure, or when the flight plan is filed enroute, the position of the aircraft; the proposed time of departure; *the route to be followed; the cruising altitude*



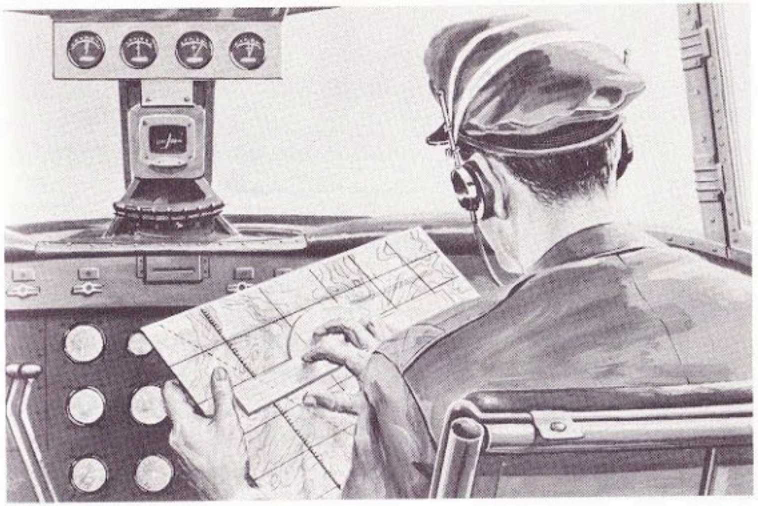
IFR altitude rules.

or *altitudes;* the proposed true air speed at cruising; the radio transmitting and receiving frequencies to be used; the point of the first intended landing; and an estimation of the time which will elapse between departure and arrival over the airport of first intended landing.

The filing of a flight plan also has a very important secondary purpose. In the event a pilot is forced to make an unscheduled landing in an area not equipped with communication facilities and fails to make scheduled position reports, an air search for the aircraft is made. Civil Air Patrol senior members play an important role in search and rescue. The information in the flight plan helps the Civil Air Patrol search team quickly locate the overdue aircraft.

IFR altitude rules.

In stating his proposed flight altitude in his flight plan, the pilot should indicate odd altitudes for easterly-northerly flights and even altitudes for westerly-southerly flights. Except where other altitude minimums have been established, IFR flights must operate so as to clear, by at least 1000 feet, the highest obstacle within five miles of the center of the intended course. In mountainous regions, a clearance of 2000 feet is required.



Rules cannot replace pilot judgment.

Within control zones and areas, ATC keeps aircraft a certain distance from one another. *Vertically* (up-and-down) *separation* is maintained by assigning different altitudes to different aircraft; *longitudinally* (forward-and-backward) *separation,* by establishing minimum time separation between different aircraft on the same course; and *laterally* (right side-and-left side) *separation,* by assigning parallel courses to different aircraft enroute to the same destination. IFR flights cruising outside control zones below 29,000 feet on magnetic courses between 0° and 179° shall fly at odd-thousand-foot, indicated, sea-level altitudes (1,000′; 3,000′; 5,000′; etc.). When they cruise on magnetic courses between 180° and 359°, they shall fly at even thousands (2,000′; 4,000′; 6,000′; etc.). For IFR flights above 29,000 feet cruising altitudes are separated vertically by 4,000 feet. For flights on magnetic courses between 0° and 179°, separations begin at 29,000 feet. For flights on magnetic courses between 180° and 359°, separtions begin at 31,000 feet.

The air traffic clearance.

The air traffic clearance issued by ATC authorizes the operation of an aircraft within a control zone or area. However, such operation must be conducted under the *specific conditions of the clearance.* Otherwise the purpose of the clearance would be defeated, since its principal object is to help the controller know at all times the position of the aircraft in flight.

In this respect, it is important for the pilot to remember that only during IFR weather conditions is it possible to keep standard separation between aircraft. During VFR weather conditions, VFR flights can be operating without the knowledge of ATC.

Generally, traffic clearances are issued for the *altitude* and *route requested on the flight plan.* However, traffic conditions sometimes make it necessary to assign altitudes and routes other than those requested. Such may be the case in areas of air traffic congestion. Flow patterns are established for these areas in order to increase the capacity of the airway. Under such conditions, ATC may change a requested route to conform to the flow pattern.

Sometimes after a clearance has been issued, it becomes necessary, in order to avoid possible conflict between aircraft in flight, for ATC to amend the clearance. Such action may be taken by an air traffic controller any time he believes it necessary.

The pilot should give close attention to the clearance when issued and not assume that the route and altitude for which his flight is cleared are those requested. When receiving clearance by radio, he should ask for a "repeat-back" of any instructions that he does not clearly understand. He always has the privilege of requesting a clearance different from the one issued by ATC when for some reason compliance with the clearance issued would not be practicable.

A pilot may also cancel an IFR flight plan at any time he is operating in VFR weather conditions. He does this by a message to the controller or to the air-ground radio station with which he is in communication. However, should subsequent IFR operation become necessary, he must file a new flight plan immediately.

Pilot responsibilities under an air traffic clearance.

After an air traffic clearance has been obtained, its conditions must be observed unless for some reason the clearance is subsequently amended. The pilot should remember that any change in *altitude, route,* or *true air speed* at cruising altitude is a change of flight plan.

The pilot must notify ATC if the radio equipment of his aircraft cannot receive omni-range signals when he is instructed to use these to identify a radio fix. For pilots are required when operating IFR to keep continuous listening watch on the proper radio channel and to make a position report at the time they are over any compulsory reporting point or any reporting point specified in the flight plan.

Position reporting is very important and must be as accurate as possible, because safe and effective traffic control depends upon accurate position reporting. It is also necessary for each position report to include an estimated time of passing the next reporting point.

It is important that pilots in flight report any unforecast weather condition encountered. They also must report, to ATC, hazardous conditions when these are encountered, whether or not these conditions have been forecast. Other reports that pilots *must make* include the altitude of the aircraft when it reaches the point to which it has been cleared, or a "holding point," and the time of its arrival there. The pilot must report his departure from one altitude for a newly assigned altitude, the time of leaving an assigned holding point, and when such happens, the fact that an approach has been missed. Still other reports may be requested by Air Traffic Control, and it is the responsibility of the pilot to conform to these requests. Finally, it is mandatory that a pilot reaching his destination "close out his flight plan."

Approach Control.

As you know, Approach Control is a service of Air Traffic Control that supervises departing and arriving IFR flights. Unless he has been instructed by ATC to do so enroute, the pilot waits until he reaches his assigned holding point before requesting instructions from Approach Control. Through the means of appropriate instructions to a pilot based upon the controller's knowledge of the positions of other aircraft within the control zone, an approaching aircraft is directed to a safe landing. IFR landings depend upon both the electronic facilities used by controllers to obtain and impart information and those used by the pilot to receive this information (See page 27). Approaches which employ electronic devices and appliances demand complete cooperation of controller and pilot.

The pilot's knowledge, skill, and judgment.

Important as are the rules of air traffic and valuable as are the tools of communication and navigation, the quality of judgment exercised by the pilot of the aircraft is the most significant factor in successful air traffic regulation and safety of aircraft operation. Rules and regulations can only define patterns of behavior. Electronic devices can only convey information and instructions. Unless the pilot disciplines himself to respect the rules of flight and to follow them and unless he is capable of basing his flight procedures upon the instructions and information he receives, both rules and instructional guidance will have been wasted.

Good operating practices.

Obviously those who use the facilities of airports and airways must observe carefully the air traffic rules established in the interest of safe flying. However, quite frequently air traffic conflicts occur when no rule has been violated. As a matter of fact, rules cannot replace good pilot judgment in the planning and conducting of a flight.

Pilots should be cautious about exercising the prerogatives of VFR flight. For example, pilots operating VFR should use good judgment and stay away from approach areas when visibility is down to three or four miles.

Pilots should be alert at all times. Air collisions occur most often when weather conditions are excellent and pilot's attention becomes relaxed.

Good judgment dictates that a pilot, although he has the right of way, should give way to approaching aircraft that get too close.

In the interest of best possible judgment, pilots whenever possible should use the designated airways, operate near the center of the Victor airways, follow IFR procedures even when operating VFR, conduct IFR operations unless weather is well above VFR minimums, and when conducting an IFR operation, make a written record of the condition of his ATC clearance.

SUMMARY

In theory, an aircraft can fly an infinite number of paths through the air from any surface point to any other. In practice, the paths of flight lead from airport to airport. In practice, aircraft land and take-off from land or water areas suitable for these purposes. Aircraft not only need proper landing and take-off facilities, they also need maintenance and repair facilities. Moreover, those who use aircraft need services and accommodations which the airport must provide.

Much can be learned about the nature of a specific airport or a specific airway from an aeronautical chart such as pilots use. For example, the chart reveals the type and size of an airport, the radio facilities it uses, and its altitude and location. The chart also shows the location of the civil airways, the magnetic direction they follow, the type of radio beams and markers that they use, the position of check points, and the geographical location of radio facilities and communications stations along them.

Airway and airport developments are keeping pace with aircraft and engine developments. These developments are mainly in the fields of airport engineering and aviation electronics. In terms of the relative importance of these two developmental areas, progress in the latter is of the most significance. Consequently, the student of airports and airways must reach some general understandings of the scientific principles underlying the devices which are used in airport and airway operation.

The radio signals, which are used in ground to air communications and to mark airways, are made possible because men have learned how to control the nature of radio wave frequencies. The electron tube is one of the devices which helps establish such control.

Through use of one type of electron tube, a faint radio signal can be amplified by a radio receiver. When this is done, a very weak electromotive force can be increased until it is strong enough to activate the diaphragms of both the earphones used by a pilot and the indicator of an electronic instrument. This is possible because one of the functions of the electron tube is the same as that of an electric generator or battery—to generate electricity. Each day sees new discoveries made in the field of electronics. The scientific application

of these discoveries will continue to bring about improvements in the tools of aviation.

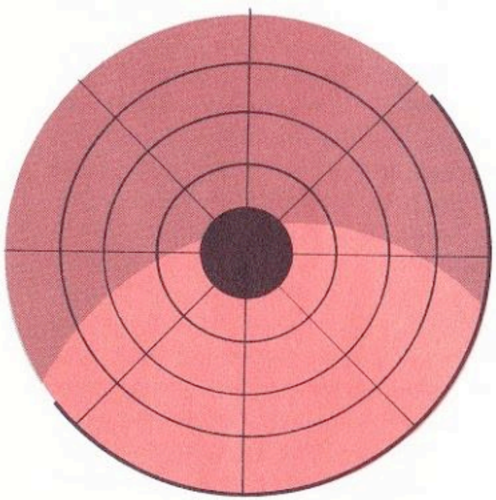
Airports are necessary for many obvious reasons. There are other reasons for their importance that may be overlooked by the airplane passenger or the airport visitor. Among these is the provision by the airport of administrative centers for the control of the several aspects of air traffic. Among the services administered by airport centers are (a) Flight Assistance Service; (b) Air Traffic Control, which includes *Airport Traffic Control, Approach Control* and *Air Route Traffic Control;* (c) Radio Communications, and (d) Weather Bureau Observation and Forecasting.

Some of the flight services whose administrative centers may be housed at an airport extend along the civil airways. The use of electronic devices to control air traffic along an airway is the factor which makes an airway of a path of flight. It is true that through the use of modern electronic devices, such as VORTAC a pilot, whether or not he is on a civil airway, may fly an exact and direct course from the airport of his flight's origin to the airport of its destination. However, a flight which does not follow a designated civil airway cannot profit by many ATC services that otherwise would be available.

In the interest of aviation safety and air traffic assistance and control, air traffic rules have been established. The rules relate chiefly to weather minimums, flight altitudes, and traffic patterns to be used under different circumstances. An aircraft observes one set of rules when the weather permits flight by reference to objects and landmarks on the ground (VFR), another set when the weather requires the use of special instruments (IFR). More exacting rules govern flight in control zones than govern flight in control areas. While air traffic rules extend to airspace elsewhere than that of control zones and areas, these in the main relate to procedures which cannot be supervised by Air Traffic Control (ATC).

In the final analysis, effective air traffic control depends upon the integrity and good judgment of the pilot who operates an aircraft. IFR operations must always be cleared by ATC in terms of a flight plan filed by the pilot in command. A wise pilot will not chance VFR operations when weather conditions are doubtful. Moreover, he will accept the responsibilities imposed on him by the ATC clearance he received. His course of action will be in accord with these responsibilities.

Airports and airways are of principal importance because without them and the equipment they employ, aircraft would have no system of organized operation.



NATIONAL EDUCATIONAL ADVISORY COMMITTEE

Emmett A. Betts
Director, Betts Reading Clinic

Willis C. Brown
Specialist for Aviation Education
Division of State and Local School Systems
Office of Education

Leslie A. Bryan
Director, Institute of Aviation
University of Illinois

John H. Furbay
Director
Air World Education
Trans-World Airlines, Inc.

George N. Gardner
Superintendent, Educational Services
Pan American World Airways System

John L. Goodwin
Associate Professor
University of California
Department of Business Administration

Dawson C. McDowell
Director, Institute of Tropical Meteorology
University of Puerto Rico

Merlyn McLaughlin, Lt. Col., USAF
58 Gruber Street
Des Moines, Iowa

Raymond O. Mertes
Director, School and College Service
United Air Lines

Kenneth E. Newland
Occupations Division
Stephens College

Willoughby E. Sams, Consultant
Aviation Education
California State Department of Education

Harry C. Schmid
State Director
Vocational Division
Department of Education
State of Minnesota

Frank E. Sorenson
Professor of Education
Teachers College
The University of Nebraska

Roland H. Spaulding
Professor in Education in Charge of Aeronautical Education
New York University
School of Education

Parker Van Zandt
International Staff, NATO
USRO Defense I

Paul A. Wilkinson
Denver Public Schools

Harry Zaritsky
Audio-Visual Division
Naval Medical School
National Naval Medical Center

Jordan L. Larson
Superintendent of Schools
Mount Vernon, New York

AVIATION EDUCATION PERSONNEL

Mervin K. Strickler, Jr.
Chief of Aviation Education

Charles W. Webb, Assistant Chief of Aviation Education

Harold E. Mehrens, Director, Editorial and Curriculum Division

William E. Rowland, Director, Audio Visual Training Aids Division

Charles J. Wood, Assistant Director, Audio Visual Training Aids Division

Everett E. Collin, North Central Region

Arthur I. Martin, Southwestern Region

John M. Ogle, Rocky Mountain Region

John E. Sims, Southeastern Region

John V. Sorenson, Pacific Region