Chapter 13

Airspace

This chapter introduces the various classifications of airspace and provides information on the requirements to operate in such airspace. For further information, consult the *Aeronautical Information Manual* (AIM) and 14 CFR parts 71, 73, and 91.

The two categories of airspace are: regulatory and nonregulatory. Within these two categories there are four types: controlled, uncontrolled, special use, and other airspace.

Figure 13-1 presents a profile view of the dimensions of various classes of airspace. Figure 13-2 gives the basic weather minimums for operating in the different classes of airspace. Figure 13-3 lists the operational and equipment requirements. It will be helpful to refer to these figures as this chapter is studied. Also there are excerpts from sectional charts in Chapter 14—Navigation, that will show how airspace is depicted.

CONTROLLED AIRSPACE

Controlled airspace is a generic term that covers the different classifications of airspace and defined dimensions within which air traffic control service is provided in accordance with the airspace classification. Controlled airspace consists of:

- Class A
- Class B
- Class C
- Class D
- Class E

CLASS A AIRSPACE

Class A airspace is generally the airspace from 18,000 feet mean sea level (MSL) up to and including FL600, including the airspace overlying the waters within 12 nautical miles (NM) of the coast of the 48 contiguous states and Alaska. Unless otherwise authorized, all operation in Class A airspace will be conducted under instrument flight rules (IFR).

CLASS B AIRSPACE

Class B airspace is generally the airspace from the surface to 10,000 feet MSL surrounding the nation's busiest airports. The configuration of Class B airspace is individually tailored to the needs of a particular area and consists of a surface area and two or more layers. Some Class B airspace resembles an upside-down wedding cake. At least a private pilot certificate is required to operate in Class B airspace; however, there is an exception to this requirement. Student pilots or recreational pilots seeking private pilot certification may operate in the airspace and land at other than specified primary airports within the airspace if they have received training and had their logbook endorsed by a certified flight instructor in accordance with Title 14 of the Code of Federal Regulations (14 CFR) part 61.

CLASS C AIRSPACE

Class C airspace generally extends from the surface to 4,000 feet above the airport elevation surrounding those airports having an operational control tower, that are serviced by a radar approach control, and with a certain number of IFR operations or passenger enplanements. This airspace is charted in feet

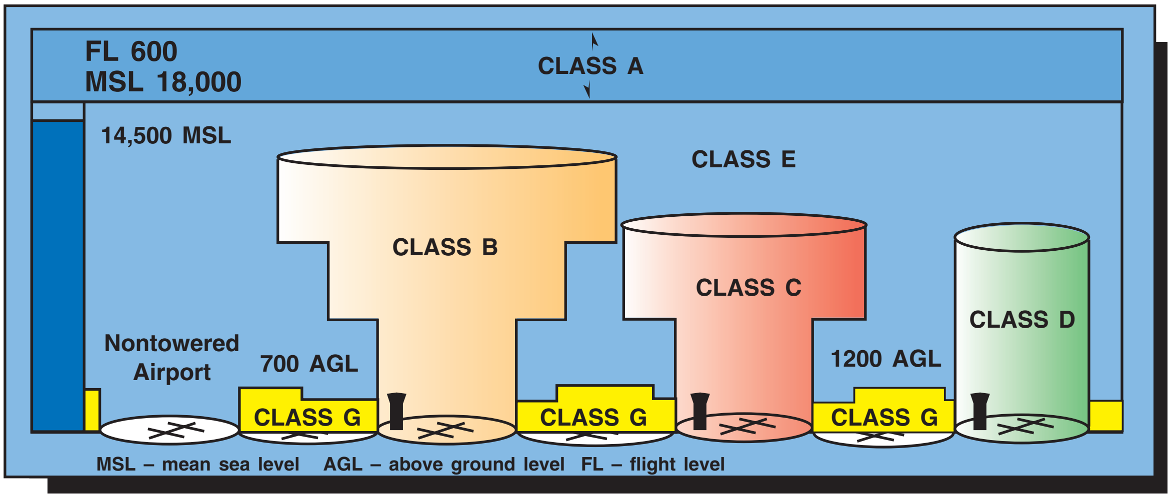

Figure 13-1. Airspace profile.

BASIC VFR WEATHER MINIMUMS		
Airspace	**Flight Visibility**	**Distance from Clouds**
Class A	Not Applicable	Not Applicable
Class B	3 statute miles	Clear of Clouds
Class C	3 statute miles	500 feet below 1,000 feet above 2,000 feet horizontal
Class D	3 statute miles	500 feet below 1,000 feet above 2,000 feet horizontal
Class E Less than 10,000 feet MSL	3 statute miles	500 feet below 1,000 feet above 2,000 feet horizontal
At or above 10,000 feet MSL	5 statute miles	1,000 feet below 1,000 feet above 1 statute mile horizontal
Class G 1,200 feet or less above the surface (regardless of MSL altitude). Day, except as provided in section 91.155(b).	1 statute mile	Clear of Clouds
Night, except as provided in section 91.155(b).	3 statute miles	500 feet below 1,000 feet above 2,000 feet horizontal
More than 1,200 feet above the surface but less than 10,000 feet MSL. Day	1 statute mile	500 feet below 1,000 feet above 2,000 feet horizontal
Night	3 statute miles	500 feet below 1,000 feet above 2,000 feet horizontal
More than 1,200 feet above the surface and at or above 10,000 feet MSL.	5 statute miles	1,000 feet below 1,000 feet above 1 statute mile horizontal

Figure 13-2. Visual flight rule weather minimums.

Class Airspace	Entry Requirements	Equipment	Minimum Pilot Certificate
A	ATC Clearance	IFR Equipped	Instrument Rating
B	ATC Clearance	Two-Way Radio, Transponder with Altitude Reporting Capability	Private—Except a student or recreational pilot may operate at other than the primary airport if seeking private pilot certification and if regulatory requirements are met.
C	Two-Way Radio Communications Prior to Entry	Two-Way Radio, Transponder with Altitude Reporting Capability	No Specific Requirement
D	Two-Way Radio Communications Prior to Entry	Two-Way Radio	No Specific Requirement
E	None for VFR	No Specific Requirement	No Specific Requirement
G	None	No Specific Requirement	No Specific Requirement

Figure 13-3. Requirements for airspace operations.

MSL, and is generally of a 5 NM radius surface area that extends from the surface to 4,000 feet above the airport elevation, and a 10 NM radius area that extends from 1,200 feet to 4,000 feet above the airport elevation. There is also an outer area with a 20 NM radius, which extends from the surface to 4,000 feet above the primary airport, and this area may include one or more satellite airports.

CLASS D AIRSPACE

Class D airspace generally extends from the surface to 2,500 feet above the airport elevation surrounding those airports that have an operational control tower. The configuration of Class D airspace will be tailored to meet the operational needs of the area.

CLASS E AIRSPACE

Class E airspace is generally controlled airspace that is not designated A, B, C, or D. Except for 18,000 feet MSL, Class E airspace has no defined vertical limit, but rather it extends upward from either the surface or a designated altitude to the overlying or adjacent controlled airspace.

UNCONTROLLED AIRSPACE

CLASS G AIRSPACE

Uncontrolled airspace or Class G airspace is the portion of the airspace that has not been designated as Class A, B, C, D, or E. It is therefore designated uncontrolled airspace. Class G airspace extends from the surface to the base of the overlying Class E airspace. Although air traffic control (ATC) has no authority or responsibility to control air traffic, pilots should remember there are VFR minimums which apply to Class G airspace.

SPECIAL USE AIRSPACE

Special use airspace exists where activities must be confined because of their nature. In special use airspace, limitations may be placed on aircraft that are not a part of the activities. Special use airspace usually consists of:

- Prohibited Areas
- Restricted Areas
- Warning Areas
- Military Operation Areas
- Alert Areas
- Controlled Firing Areas

PROHIBITED AREAS

Prohibited areas are established for security or other reasons associated with the national welfare. Prohibited areas are published in the Federal Register and are depicted on aeronautical charts.

RESTRICTED AREAS

Restricted areas denote the existence of unusual, often invisible hazards to aircraft such as artillery firing, aerial gunnery, or guided missiles. An aircraft may not enter a restricted area unless permission has been obtained from the controlling agency. Restricted areas are depicted on aeronautical charts and are published in the Federal Register.

WARNING AREAS

Warning areas consist of airspace which may contain hazards to nonparticipating aircraft in international airspace. The activities may be much the same as those for a restricted area. Warning areas are established beyond the 3-mile limit. Warning areas are depicted on aeronautical charts.

MILITARY OPERATION AREAS

Military operation areas (MOA) consist of airspace of defined vertical and lateral limits established for the purpose of separating certain military training activity from IFR traffic. There is no restriction against a pilot operating VFR in these areas; however, a pilot should be alert since training activities may include acrobatic and abrupt maneuvers. MOAs are depicted on aeronautical charts.

ALERT AREAS

Alert areas are depicted on aeronautical charts and are to advise pilots that a high volume of pilot training or unusual aerial activity is taking place.

CONTROLLED FIRING AREAS

Controlled firing areas contain activities, which, if not conducted in a controlled environment, could be hazardous to nonparticipating aircraft. The difference between controlled firing areas and other special use airspace is that activities must be suspended when a spotter aircraft, radar, or ground lookout position indicates an aircraft might be approaching the area.

OTHER AIRSPACE AREAS

"Other airspace areas" is a general term referring to the majority of the remaining airspace. It includes:

- Airport Advisory Areas
- Military Training Routes (MTR)
- Temporary Flight Restrictions
- Parachute Jump Areas
- Published VFR Routes
- Terminal Radar Service Areas
- National Security Areas

AIRPORT ADVISORY AREAS

An airport advisory area is an area within 10 statute miles (SM) of an airport where a control tower is not operating, but where a flight service station (FSS) is located. At these locations, the FSS provides advisory service to arriving and departing aircraft.

MILITARY TRAINING ROUTES

Military training routes (MTR) are developed to allow the military to conduct low-altitude, high-speed training. The routes above 1,500 feet AGL are developed to be flown primarily under IFR, and the routes 1,500 feet and less are for VFR flight. The routes are identified on sectional charts by the designation "instrument (IR) or visual (VR)."

TEMPORARY FLIGHT RESTRICTIONS

An FDC NOTAM will be issued to designate a temporary flight restriction (TFR). The NOTAM will begin with the phrase "FLIGHT RESTRICTIONS" followed by the location of the temporary restriction, effective time period, area defined in statute miles, and altitudes affected. The NOTAM will also contain the FAA coordination facility and telephone number, the reason for the restriction, and any other information deemed appropriate. The pilot should check the NOTAMs as part of flight planning.

Some of the purposes for establishing a temporary restriction are:

- Protect persons and property in the air or on the surface from an existing or imminent hazard.
- Provide a safe environment for the operation of disaster relief aircraft.
- Prevent an unsafe congestion of sightseeing aircraft above an incident or event, which may generate a high degree of public interest.
- Protect declared national disasters for humanitarian reasons in the State of Hawaii.
- Protect the President, Vice President, or other public figures.
- Provide a safe environment for space agency operations.

PARACHUTE JUMP AREAS

Parachute jump areas are published in the *Airport/Facility Directory*. Sites that are used frequently are depicted on sectional charts.

PUBLISHED VFR ROUTES

Published VFR routes are for transitioning around, under, or through some complex airspace. Terms such as VFR flyway, VFR corridor, Class B airspace, VFR transition route, and terminal area VFR route have been applied to such routes. These routes are generally found on VFR terminal area planning charts.

TERMINAL RADAR SERVICE AREAS

Terminal Radar Service Areas (TRSA) are areas where participating pilots can receive additional radar services. The purpose of the service is to provide separation between all IFR operations and participating VFR aircraft.

The primary airport(s) within the TRSA become(s) Class D airspace. The remaining portion of the TRSA overlies other controlled airspace, which is normally Class E airspace beginning at 700 or 1,200 feet and established to transition to/from the en route terminal environment. TRSAs are depicted on VFR sectional charts and terminal area charts with a solid black line and altitudes for each segment. The Class D portion is charted with a blue segmented line.

Participation in TRSA services is voluntary; however, pilots operating under VFR are encouraged to contact the radar approach control and take advantage of TRSA service.

NATIONAL SECURITY AREAS

National security areas consist of airspace of defined vertical and lateral dimensions established at locations where there is a requirement for increased security and safety of ground facilities. Pilots are requested to voluntarily avoid flying through these depicted areas. When necessary, flight may be temporarily prohibited.

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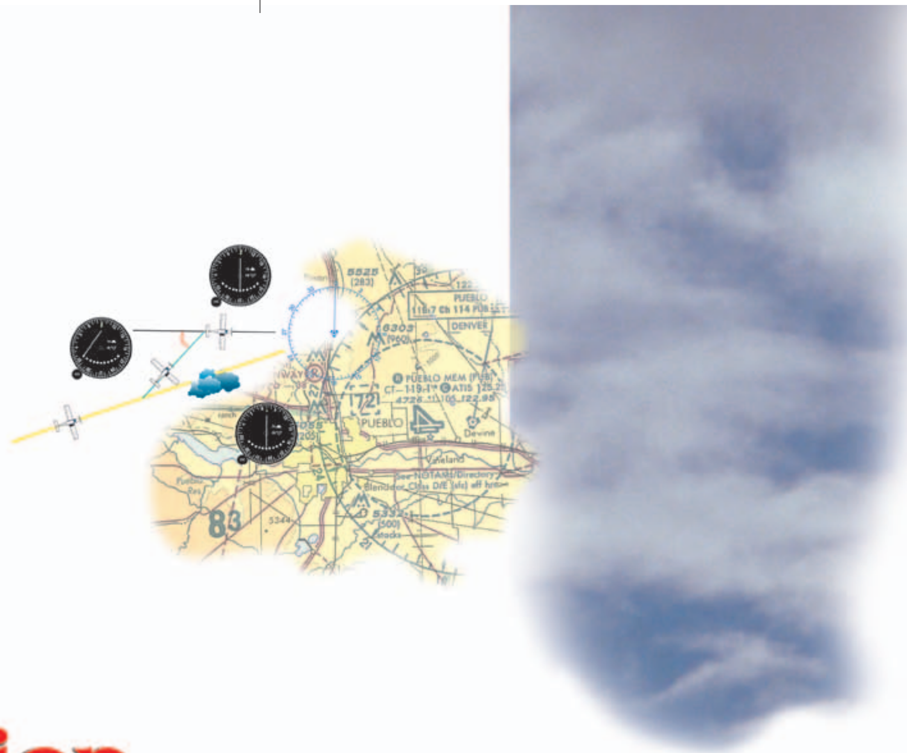
Chapter 14



Navigation

This chapter provides an introduction to cross-country flying under visual flight rules (VFR). It contains practical information for planning and executing cross-country flights for the beginning pilot.

Air navigation is the process of piloting an airplane from one geographic position to another while monitoring one's position as the flight progresses. It introduces the need for planning, which includes plotting the course on an aeronautical chart, selecting checkpoints, measuring distances, obtaining pertinent weather information, and computing flight time, headings, and fuel requirements. The methods used in this chapter include pilotage—navigating by reference to visible landmarks, dead reckoning—computations of direction and distance from a known position, and radio navigation—by use of radio aids.

AERONAUTICAL CHARTS

An aeronautical chart is the road map for a pilot flying under VFR. The chart provides information which allows pilots to track their position and provides available information which enhances safety. The three aeronautical charts used by VFR pilots are:

- Sectional Charts
- VFR Terminal Area Charts
- World Aeronautical Charts

A free catalog listing aeronautical charts and related publications including prices and instructions for ordering is available at the National Aeronautical Charting Office (NACO) Web site: www.naco.faa.gov.

SECTIONAL CHARTS

Sectional charts are the most common charts used by pilots today. The charts have a scale of 1:500,000 (1 inch = 6.86 nautical miles or approximately 8 statute miles) which allows for more detailed information to be included on the chart.

The charts provide an abundance of information, including airport data, navigational aids, airspace, and topography. Figure 14-1 on the next page is an excerpt from the legend of a sectional chart. By referring to the chart legend, a pilot can interpret most of the information on the chart. A pilot should also check the chart for other legend information, which includes air traffic control frequencies and information on airspace. These charts are revised semiannually except for some areas outside the conterminous United States where they are revised annually.

VISUAL FLIGHT RULE TERMINAL AREA CHARTS

Visual flight rule (VFR) terminal area charts are helpful when flying in or near Class B airspace. They have a scale of 1:250,000 (1 inch = 3.43 nautical miles or approximately 4 statute miles). These charts provide a more detailed display of topographical information and are revised semiannually, except for several Alaskan and Caribbean charts.

WORLD AERONAUTICAL CHARTS

World aeronautical charts are designed to provide a standard series of aeronautical charts, covering land areas of the world, at a size and scale convenient for navigation by moderate speed aircraft. They are produced at a scale of 1:1,000,000 (1 inch = 13.7 nautical miles or approximately 16 statute miles). These charts are similar to sectional charts and the symbols are the same except there is less detail due to the smaller scale. These charts are revised annually except several Alaskan charts and the Mexican/Caribbean charts which are revised every 2 years.

LATITUDE AND LONGITUDE (MERIDIANS AND PARALLELS)

The Equator is an imaginary circle equidistant from the poles of the Earth. Circles parallel to the Equator (lines running east and west) are parallels of latitude. They are used to measure degrees of latitude north or south of the Equator. The angular distance from the Equator to the pole is one-fourth of a circle or 90°. The 48 conterminous states of the United States are located between 25° and 49° N. latitude. The arrows in figure 14-2 labeled "LATITUDE" point to lines of latitude.

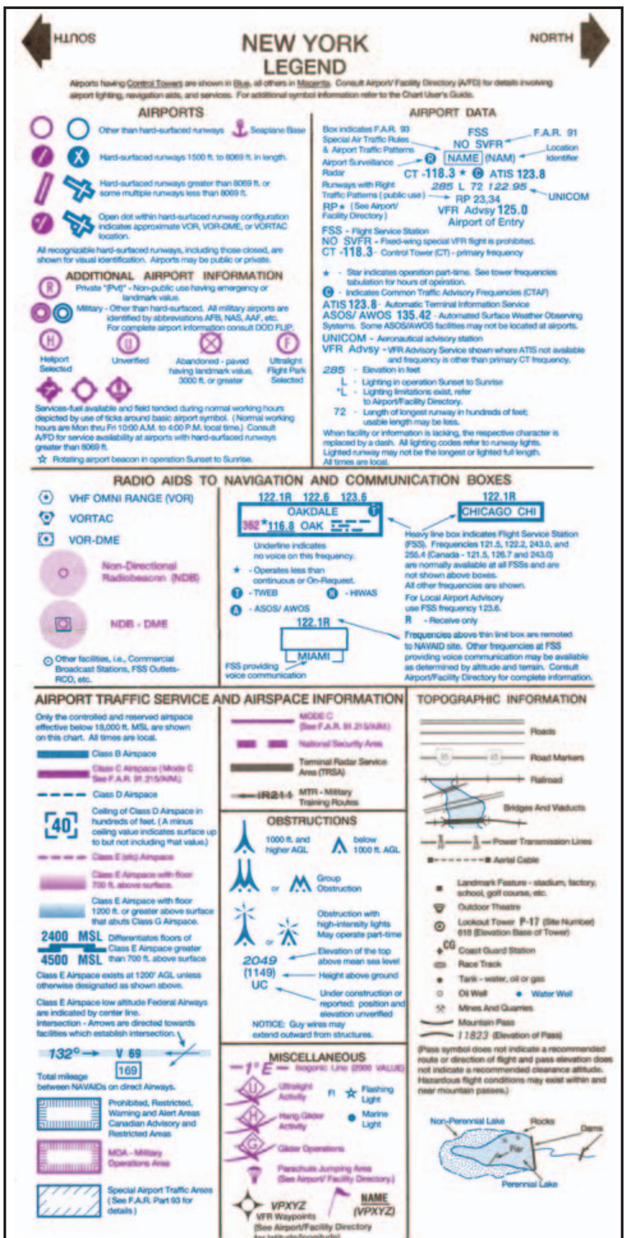


Figure 14-1. Sectional chart legend.

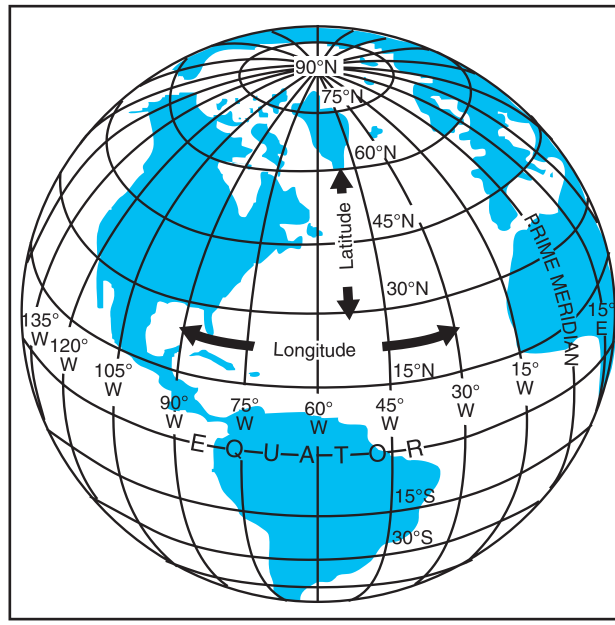


Figure 14-2. Meridians and parallels—the basis of measuring time, distance, and direction.

Meridians of longitude are drawn from the North Pole to the South Pole and are at right angles to the Equator. The "Prime Meridian" which passes through Greenwich, England, is used as the zero line from which measurements are made in degrees east and west to 180°. The 48 conterminous states of the United States are between 67° and 125° W. Longitude. The arrows in figure 14-2 labeled "LONGITUDE" point to lines of longitude.

Any specific geographical point can thus be located by reference to its longitude and latitude. Washington, DC for example, is approximately 39° N. latitude, 77° W. longitude. Chicago is approximately 42° N. latitude, 88° W. longitude.

TIME ZONES

The meridians are also useful for designating time zones. A day is defined as the time required for the Earth to make one complete rotation of 360°. Since the day is divided into 24 hours, the Earth revolves at the rate of 15° an hour. Noon is the time when the Sun is directly above a meridian; to the west of that meridian is morning, to the east is afternoon.

The standard practice is to establish a time zone for each 15° of longitude. This makes a difference of exactly 1 hour between each zone. In the United States, there are four time zones. The time zones are Eastern (75°), Central (90°), Mountain (105°), and Pacific (120°). The dividing lines are somewhat irregular because communities near the boundaries often find it more convenient to use time designations of neighboring communities or trade centers.

Figure 14-3 shows the time zones in the United States. When the Sun is directly above the 90th meridian, it is noon Central Standard Time. At the same time, it will be 1 p.m. Eastern Standard Time, 11 a.m. Mountain Standard Time, and 10 a.m. Pacific Standard Time. When "daylight saving" time is in effect, generally between the last Sunday in April and the last Sunday in October, the Sun is directly above the 75th meridian at noon, Central Daylight Time.

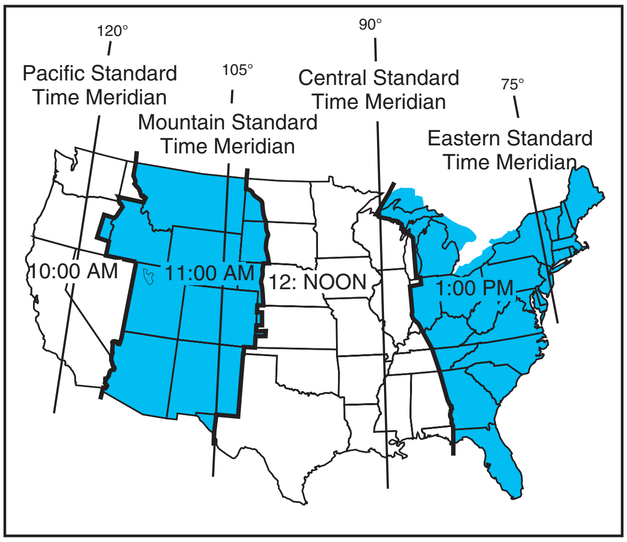


Figure 14-3. Time zones.

These time zone differences must be taken into account during long flights eastward—especially if the flight must be completed before dark. Remember, an hour is lost when flying eastward from one time zone to another, or perhaps even when flying from the western edge to the eastern edge of the same time zone. Determine the time of sunset at the destination by consulting the flight service stations (AFSS/FSS) or National Weather Service (NWS) and take this into account when planning an eastbound flight.

In most aviation operations, time is expressed in terms of the 24-hour clock. Air traffic control instructions, weather reports and broadcasts, and estimated times of arrival are all based on this system. For example: 9 a.m. is expressed as 0900, 1 p.m. is 1300, and 10 p.m. is 2200.

Because a pilot may cross several time zones during a flight, a standard time system has been adopted. It is called Universal Coordinated Time (UTC) and is often referred to as Zulu time. UTC is the time at the 0° line of longitude which passes through Greenwich, England. All of the time zones around the world are based on this reference. To convert to this time, a pilot should do the following:

Eastern Standard Time..........Add 5 hours

Central Standard Time..........Add 6 hours

Mountain Standard Time...... Add 7 hours

Pacific Standard Time.......... Add 8 hours

For daylight saving time, 1 hour should be subtracted from the calculated times.

MEASUREMENT OF DIRECTION

By using the meridians, direction from one point to another can be measured in degrees, in a clockwise direction from true north. To indicate a course to be followed in flight, draw a line on the chart from the point of departure to the destination and measure the angle which this line forms with a meridian. Direction is expressed in degrees, as shown by the compass rose in figure 14-4.

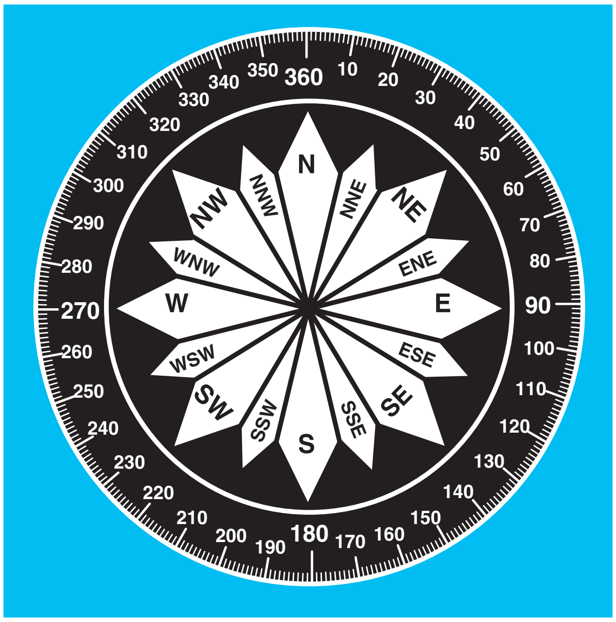


Figure 14-4. Compass rose.

Because meridians converge toward the poles, course measurement should be taken at a meridian near the midpoint of the course rather than at the point of departure. The course measured on the chart is known as the true course. This is the direction measured by reference to a meridian or true north. It is the direction of intended flight as measured in degrees clockwise from true north.

As shown in figure 14-5, the direction from A to B would be a true course of 065°, whereas the return trip (called the reciprocal) would be a true course of 245°.

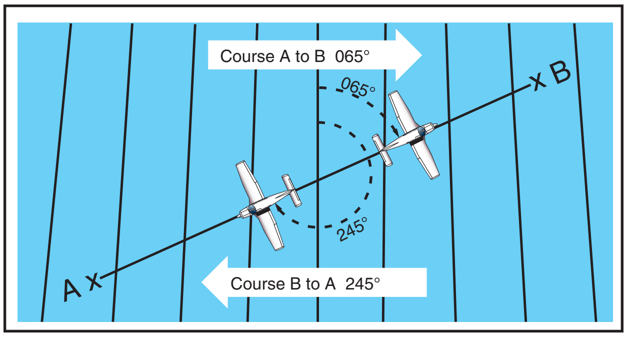


Figure 14-5. Courses are determined by reference to meridians on aeronautical charts.

The true heading is the direction in which the nose of the airplane points during a flight when measured in degrees clockwise from true north. Usually, it is necessary to head the airplane in a direction slightly different from the true course to offset the effect of wind. Consequently, numerical value of the true heading may not correspond with that of the true course. This will be discussed more fully in subsequent sections in this chapter. For the purpose of this discussion, assume a no-wind condition exists under which heading and course would coincide. Thus, for a true course of 065°, the true heading would be 065°. To use the compass accurately, however, corrections must be made for magnetic variation and compass deviation.

VARIATION

Variation is the angle between true north and magnetic north. It is expressed as east variation or west variation depending upon whether magnetic north (MN) is to the east or west of true north (TN).

The north magnetic pole is located close to 71° N. latitude, 96° W. longitude and is about 1,300 miles from the geographic or true north pole, as indicated in figure 14-6. If the Earth were uniformly magnetized, the compass needle would point toward the magnetic pole, in which case the variation between true north (as shown by the geographical meridians) and magnetic north (as shown by the magnetic meridians) could be measured at any intersection of the meridians.

Actually, the Earth is not uniformly magnetized. In the United States, the needle usually points in the general direction of the magnetic pole, but it may vary in certain geographical localities by many degrees. Consequently, the exact amount of variation at thousands of selected locations in the United States has been carefully determined. The amount and the direction of variation, which change slightly from time to time, are shown on most aeronautical charts as broken magenta lines, called isogonic lines, which connect points of equal magnetic

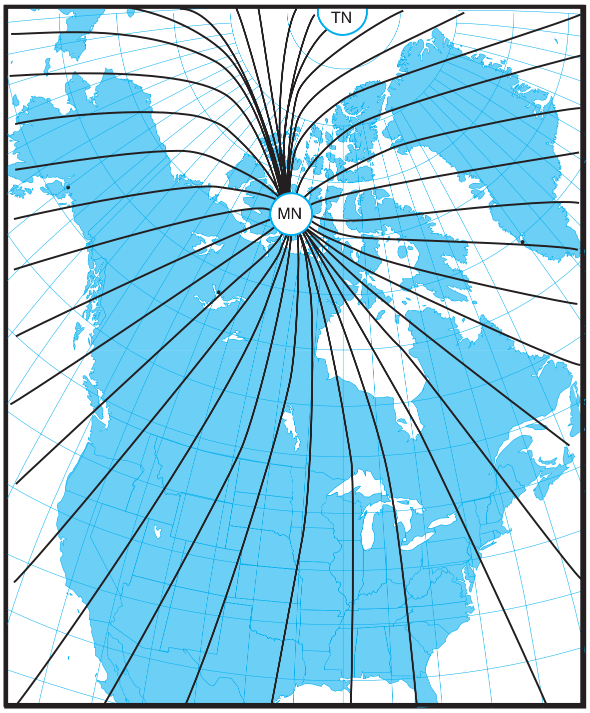


Figure 14-6. Isogonic chart. Magnetic meridians are in black; geographic meridians and parallels are in blue. Variation is the angle between a magnetic and geographic meridian.

variation. (The line connecting points at which there is no variation between true north and magnetic north is the agonic line.) An isogonic chart is shown in figure 14-6. Minor bends and turns in the isogonic and agonic lines are caused by unusual geological conditions affecting magnetic forces in these areas.

On the west coast of the United States, the compass needle points to the east of true north; on the east coast, the compass needle points to the west of true north. Zero degree variation exists on the agonic line, where magnetic north and true north coincide. This line runs roughly west of the Great Lakes, south through Wisconsin, Illinois, western Tennessee, and along the border of Mississippi and Alabama. [Compare figures 14-7 and 14-8.]

Because courses are measured in reference to geographical meridians which point toward true north, and these courses are maintained by reference to the compass which points along a magnetic meridian in the general direction of magnetic north, the true direction must be converted into magnetic direction for the purpose of flight. This conversion is made by adding or subtracting the variation which is indicated by the nearest isogonic line on the chart. The true heading, when corrected for variation, is known as magnetic heading.

If the variation is shown as "9°E," this means that magnetic north is 9° east of true north. If a true heading of 360° is to be flown, 9° must be subtracted from 360°, which results in a magnetic heading of 351°. To fly

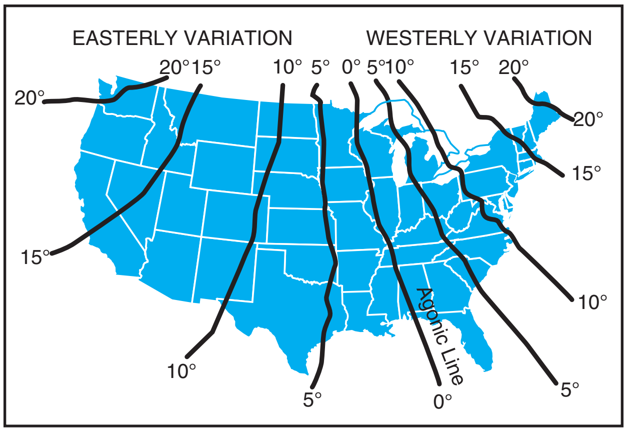


Figure 14-7. A typical isogonic chart. The black lines are isogonic lines which connect geographic points with identical magnetic variation.

east, a magnetic heading of 081° (090° – 9°) would be flown. To fly south, the magnetic heading would be 171° (180° – 9°). To fly west, it would be 261° (270° – 9°). To fly a true heading of 060°, a magnetic heading of 051° (060° – 9°) would be flown.

Remember, to convert true course or heading to magnetic course or heading, note the variation shown by the nearest isogonic line. If variation is west, add; if east, subtract. One method for remembering whether to add or subtract variation is the phrase "east is least (subtract) and west is best (add)."

DEVIATION

Determining the magnetic heading is an intermediate step necessary to obtain the correct compass heading for the flight. To determine compass heading, a correction for deviation must be made. Because of magnetic influences within the airplane such as electrical circuits, radio, lights, tools, engine, and magnetized metal parts, the compass needle is frequently deflected from its normal reading. This deflection is deviation. The deviation is different for each airplane, and it also may vary for different headings in the same airplane. For instance, if magnetism in the engine attracts the north end of the compass, there would be no effect when the plane is on a heading of magnetic north. On easterly or westerly headings, however, the compass indications would be in error, as shown in figure 14-9. Magnetic attraction can come from many other parts of the airplane; the assumption of attraction in the engine is merely used for the purpose of illustration.

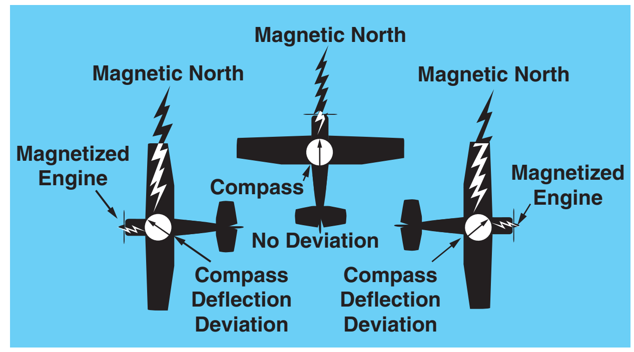


Figure 14-9. Magnetized portions of the airplane cause the compass to deviate from its normal indications.

Some adjustment of the compass, referred to as compensation, can be made to reduce this error, but the remaining correction must be applied by the pilot.

Proper compensation of the compass is best performed by a competent technician. Since the magnetic forces within the airplane change, because of landing shocks, vibration, mechanical work, or changes in equipment, the pilot should occasionally have the deviation of the compass checked. The procedure used to check the deviation (called "swinging the compass") is briefly outlined.

The airplane is placed on a magnetic compass rose, the engine started, and electrical devices normally used (such as radio) are turned on. Tailwheel-type airplanes should be jacked up into flying position. The airplane is aligned with magnetic north indicated on the compass

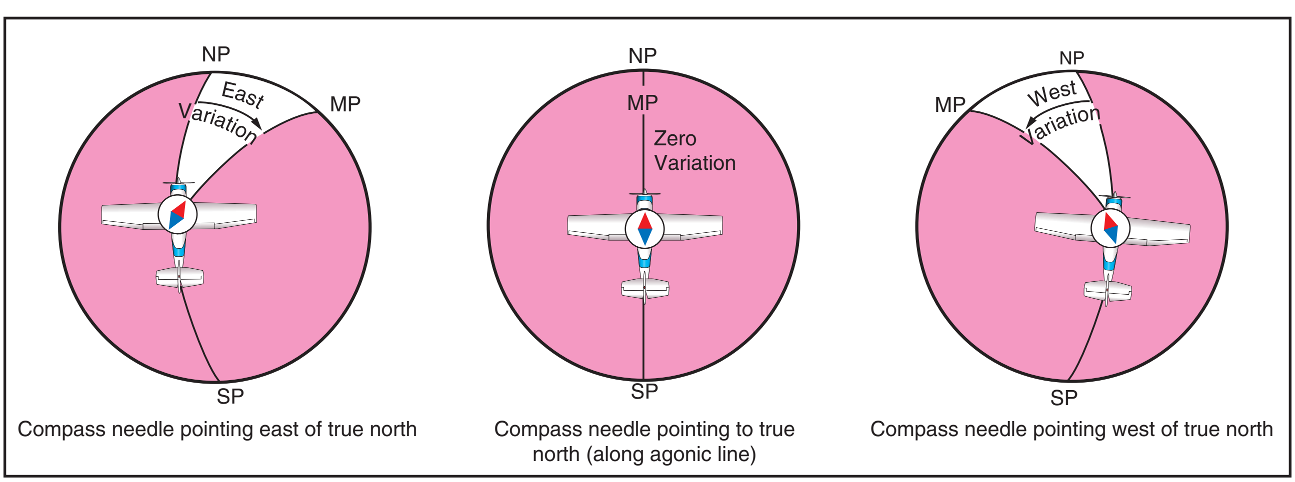


Figure 14-8. Effect of variation on the compass.

rose and the reading shown on the compass is recorded on a deviation card. The airplane is then aligned at 30° intervals and each reading is recorded. If the airplane is to be flown at night, the lights are turned on and any significant changes in the readings are noted. If so, additional entries are made for use at night.

The accuracy of the compass can also be checked by comparing the compass reading with the known runway headings.

A deviation card, similar to figure 14-10, is mounted near the compass, showing the addition or subtraction required to correct for deviation on various headings, usually at intervals of 30°. For intermediate readings, the pilot should be able to interpolate mentally with sufficient accuracy. For example, if the pilot needed the correction for 195° and noted the correction for 180° to be 0° and for 210° to be +2°, it could be assumed that the correction for 195° would be +1°. The magnetic heading, when corrected for deviation, is known as compass heading.

FOR (MAGNETIC)..........	N	30	60	E	120	150
STEER (COMPASS).......	0	28	57	86	117	148
FOR (MAGNETIC)..........	S	210	240	W	300	330
STEER (COMPASS).......	180	212	243	274	303	332

Figure 14-10. Compass deviation card.

The following method is used by many pilots to determine compass heading: After the true course (TC) is measured, and wind correction applied resulting in a true heading (TH), the sequence TH ± variation (V) = MH ± deviation (D) = compass heading (CH) is followed to arrive at compass heading. [Figure 14-11]

EFFECT OF WIND

The preceding discussion explained how to measure a true course on the aeronautical chart and how to make corrections for variation and deviation, but one important factor has not been considered—wind. As discussed in the study of the atmosphere, wind is a mass of air moving over the surface of the Earth in a definite direction. When the wind is blowing from the north at 25 knots, it simply means that air is moving southward over the Earth's surface at the rate of 25 nautical miles (NM) in 1 hour.

Under these conditions, any inert object free from contact with the Earth will be carried 25 NM southward in 1 hour. This effect becomes apparent when such things as clouds, dust, and toy balloons are observed being blown along by the wind. Obviously, an airplane flying within the moving mass of air will be similarly affected. Even though the airplane does not float freely

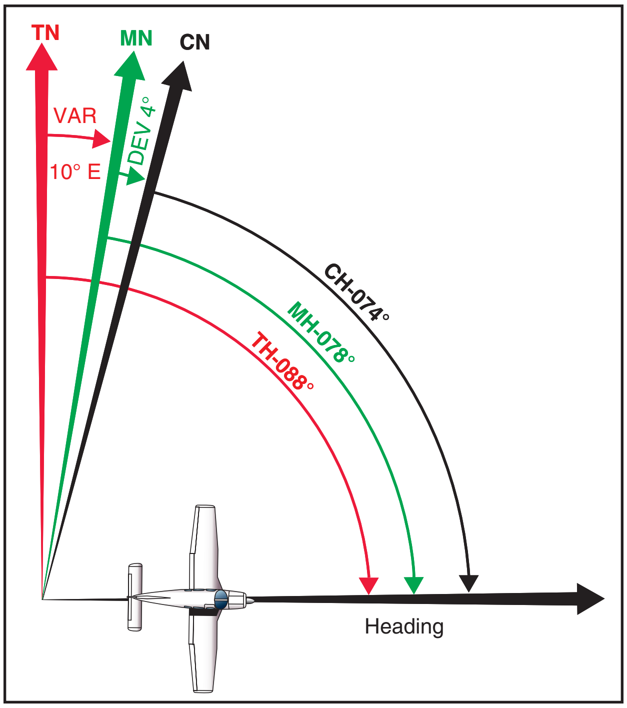


Figure 14-11. Relationship between true, magnetic, and compass headings for a particular instance.

with the wind, it moves through the air at the same time the air is moving over the ground, thus is affected by wind. Consequently, at the end of 1 hour of flight, the airplane will be in a position which results from a combination of these two motions:

- the movement of the air mass in reference to the ground, and
- the forward movement of the airplane through the air mass.

Actually, these two motions are independent. So far as the airplane's flight through the air is concerned, it makes no difference whether the mass of air through which the airplane is flying is moving or is stationary. A pilot flying in a 70-knot gale would be totally unaware of any wind (except for possible turbulence) unless the ground were observed. In reference to the ground, however, the airplane would appear to fly faster with a tailwind or slower with a headwind, or to drift right or left with a crosswind.

As shown in figure 14-12, an airplane flying eastward at an airspeed of 120 knots in still air, will have a groundspeed exactly the same—120 knots. If the mass of air is moving eastward at 20 knots, the airspeed of the airplane will not be affected, but the progress of the airplane over the ground will be 120 plus 20, or a groundspeed of 140 knots. On the other hand, if the mass of air is moving westward at 20 knots, the airspeed of the airplane still remains the same, but groundspeed becomes 120 minus 20 or 100 knots.

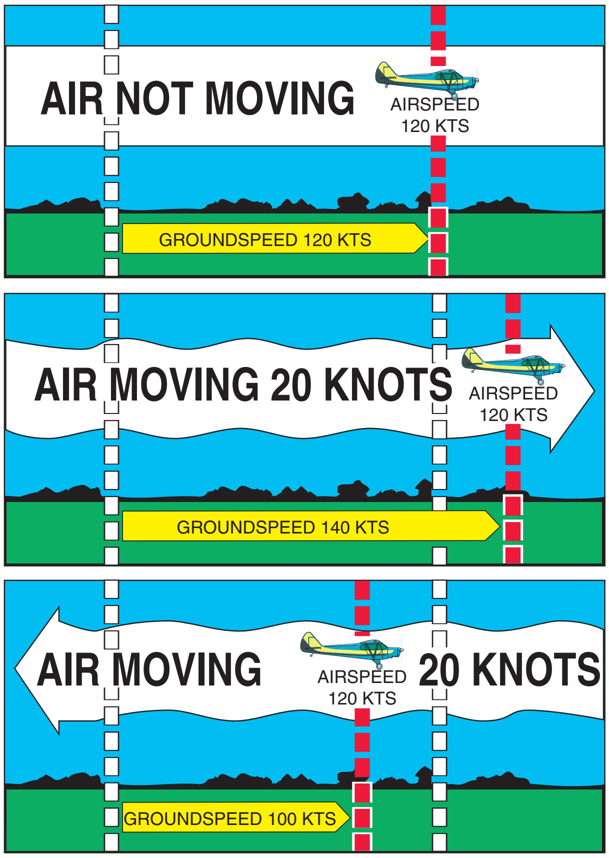


Figure 14-12. Motion of the air affects the speed with which airplanes move over the Earth's surface. Airspeed, the rate at which an airplane moves through the air, is not affected by air motion.

Assuming no correction is made for wind effect, if the airplane is heading eastward at 120 knots, and the air mass moving southward at 20 knots, the airplane at the end of 1 hour will be almost 120 miles east of its point of departure because of its progress through the air. It will be 20 miles south because of the motion of the air. Under these circumstances, the airspeed remains 120 knots, but the groundspeed is determined by combining the movement of the airplane with that of the air mass. Groundspeed can be measured as the distance from the point of departure to the position of the airplane at the end of 1 hour. The groundspeed can be computed by the time required to fly between two points a known distance apart. It also can be determined before flight by constructing a wind triangle, which will be explained later in this chapter. [Figure 14-13]

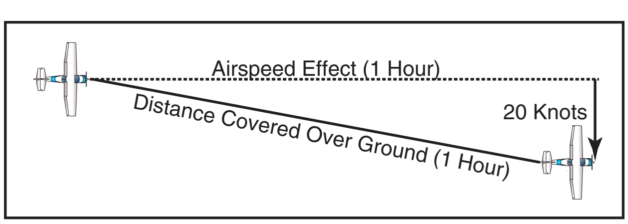


Figure 14-13. Airplane flightpath resulting from its airspeed and direction, and the windspeed and direction.

The direction in which the plane is pointing as it flies is heading. Its actual path over the ground, which is a combination of the motion of the airplane and the motion of the air, is track. The angle between the heading and the track is drift angle. If the airplane's heading coincides with the true course and the wind is blowing from the left, the track will not coincide with the true course. The wind will drift the airplane to the right, so the track will fall to the right of the desired course or true course. [Figure 14-14]

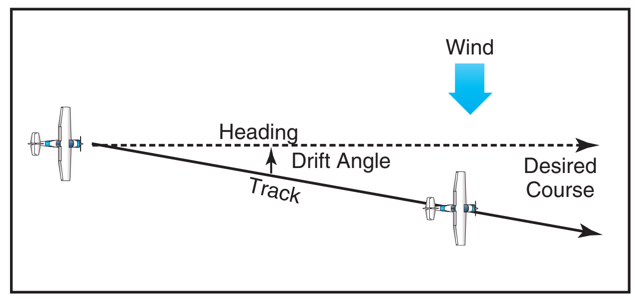


Figure 14-14. Effects of wind drift on maintaining desired course.

By determining the amount of drift, the pilot can counteract the effect of the wind and make the track of the airplane coincide with the desired course. If the mass of air is moving across the course from the left, the airplane will drift to the right, and a correction must be made by heading the airplane sufficiently to the left to offset this drift. To state in another way, if the wind is from the left, the correction will be made by pointing the airplane to the left a certain number of degrees, therefore correcting for wind drift. This is wind correction angle and is expressed in terms of degrees right or left of the true course. [Figure 14-15]

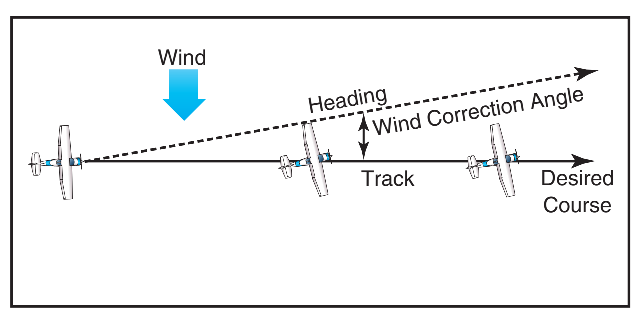


Figure 14-15. Establishing a wind correction angle that will counteract wind drift and maintain the desired course.

To summarize:

- **COURSE—**is the intended path of an airplane over the ground; or the direction of a line drawn on a chart representing the intended airplane path, expressed as the angle measured from a specific reference datum clockwise from 0° through 360° to the line.

- **HEADING—**is the direction in which the nose of the airplane points during flight.
- **TRACK—**is the actual path made over the ground in flight. (If proper correction has been made for the wind, track and course will be identical.)
- **DRIFT ANGLE—**is the angle between heading and track.
- **WIND CORRECTION ANGLE—**is correction applied to the course to establish a heading so that track will coincide with course.
- **AIRSPEED—**is the rate of the airplane's progress through the air.
- **GROUNDSPEED—**is the rate of the airplane's in-flight progress over the ground.

BASIC CALCULATIONS

Before a cross-country flight, a pilot should make common calculations for time, speed, and distance, and the amount of fuel required.

CONVERTING MINUTES TO EQUIVALENT HOURS

It frequently is necessary to convert minutes into equivalent hours when solving speed, time, and distance problems. To convert minutes to hours, divide by 60 (60 minutes = 1 hour). Thus, 30 minutes 30/60 = 0.5 hour. To convert hours to minutes, multiply by 60. Thus, 0.75 hour equals 0.75 x 60 = 45 minutes.

Time T = D/GS

To find the **time** (T) in flight, divide the **distance** (D) by the **groundspeed** (GS). The time to fly 210 nautical miles at a groundspeed of 140 knots is 210 divided by 140, or 1.5 hours. (The 0.5 hour multiplied by 60 minutes equals 30 minutes.) Answer: 1:30.

Distance D = GS X T

To find the distance flown in a given time, multiply groundspeed by time. The distance flown in 1 hour 45 minutes at a groundspeed of 120 knots is 120 x 1.75, or 210 nautical miles.

Groundspeed GS = D/T

To find the groundspeed, divide the distance flown by the time required. If an airplane flies 270 nautical miles in 3 hours, the groundspeed is 270 divided by 3 = 90 knots.

CONVERTING KNOTS TO MILES PER HOUR

Another conversion is that of changing knots to miles per hour. The aviation industry is using knots more frequently than miles per hour, but it might be well to discuss the conversion for those who do use miles per hour when working with speed problems. The National Weather Service reports both surface winds and winds aloft in knots. However, airspeed indicators in some airplanes are calibrated in miles per hour (although many are now calibrated in both miles per hour and knots). Pilots, therefore, should learn to convert windspeeds in knots to miles per hour.

A knot is 1 nautical mile per hour. Because there are 6,076.1 feet in a nautical mile and 5,280 feet in a statute mile, the conversion factor is 1.15. To convert knots to miles per hour, multiply knots by 1.15. For example: a windspeed of 20 knots is equivalent to 23 miles per hour.

Most flight computers or electronic calculators have a means of making this conversion. Another quick method of conversion is to use the scales of nautical miles and statute miles at the bottom of aeronautical charts.

FUEL CONSUMPTION

Airplane fuel consumption is computed in gallons per hour. Consequently, to determine the fuel required for a given flight, the time required for the flight must be known. Time in flight multiplied by rate of consumption gives the quantity of fuel required. For example, a flight of 400 NM at a groundspeed of 100 knots requires 4 hours. If the plane consumes 5 gallons an hour, the total consumption will be 4 x 5, or 20 gallons.

The rate of fuel consumption depends on many factors: condition of the engine, propeller pitch, propeller r.p.m., richness of the mixture, and particularly the percentage of horsepower used for flight at cruising speed. The pilot should know the approximate consumption rate from cruise performance charts, or from experience. In addition to the amount of fuel required for the flight, there should be sufficient fuel for reserve.

FLIGHT COMPUTERS

Up to this point, only mathematical formulas have been used to determine such items as time, distance, speed, and fuel consumption. In reality, most pilots will use a mechanical or electronic flight computer. These devices can compute numerous problems associated with flight planning and navigation. The mechanical or electronic computer will have an instruction book and most likely sample problems so the pilot can become familiar with its functions and operation. [Figure 14-16]

PLOTTER

Another aid in flight planning is a plotter, which is a protractor and ruler. The pilot can use this when determining true course and measuring distance. Most plotters have a ruler which measures in both

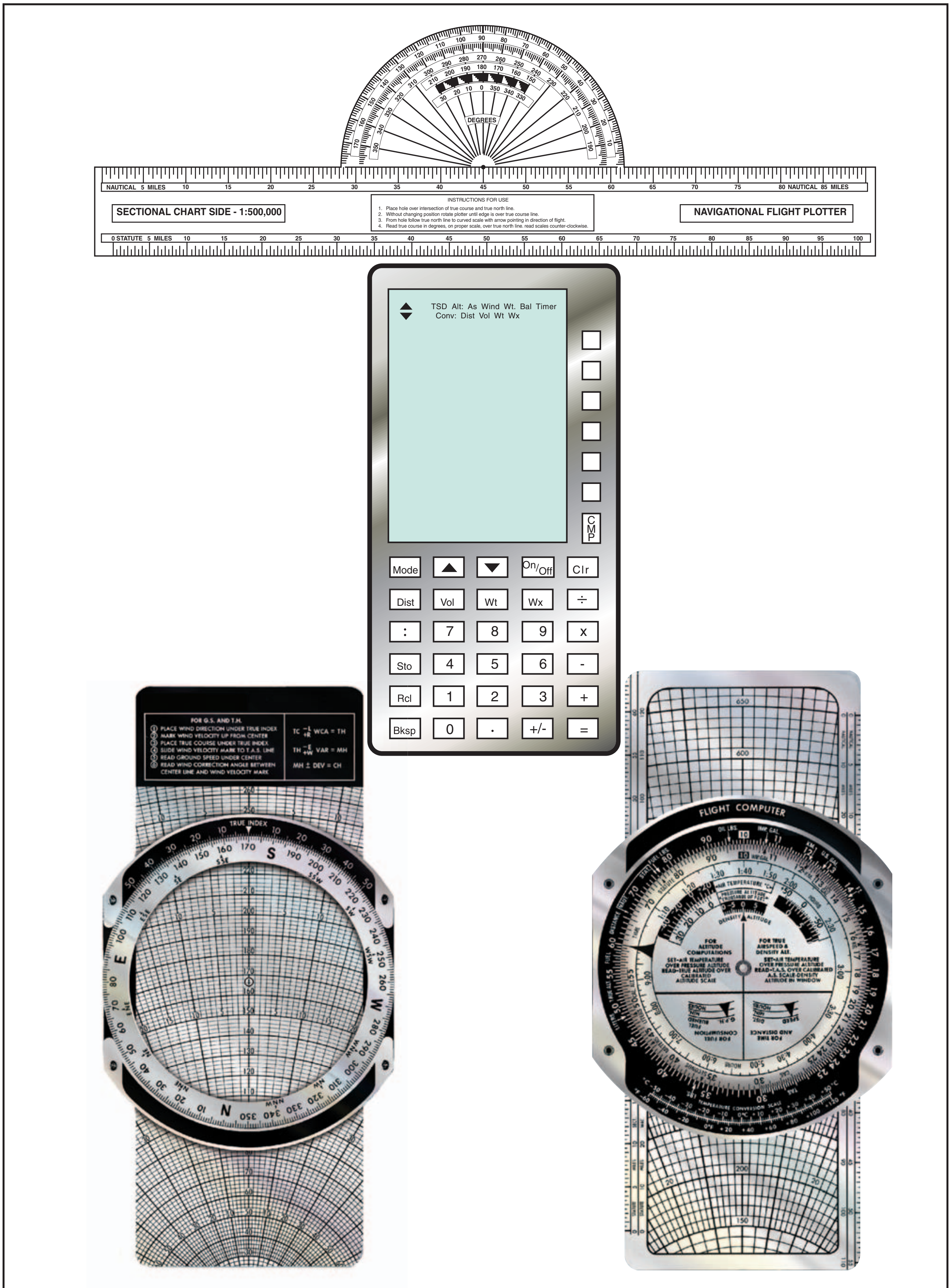


Figure 14-16. A picture of the computational and wind side of a common mechanical computer, an electronic computer, and plotter.

nautical and statute miles and has a scale for a sectional chart on one side and a world aeronautical chart on the other. [Figure 14-16]

PILOTAGE

Pilotage is navigation by reference to landmarks or checkpoints. It is a method of navigation that can be used on any course that has adequate checkpoints, but it is more commonly used in conjunction with dead reckoning and VFR radio navigation.

The checkpoints selected should be prominent features common to the area of the flight. Choose checkpoints that can be readily identified by other features such as roads, rivers, railroad tracks, lakes, and power lines. If possible, select features that will make useful boundaries or brackets on each side of the course, such as highways, rivers, railroads, and mountains. A pilot can keep from drifting too far off course by referring to and not crossing the selected brackets. Never place complete reliance on any single checkpoint. Choose ample checkpoints. If one is missed, look for the next one while maintaining the heading. When determining position from checkpoints, remember that the scale of a sectional chart is 1 inch = 8 statute miles or 6.86 nautical miles. For example, if a checkpoint selected was approximately one-half inch from the course line on the chart, it is 4 statue miles or 3.43 nautical miles from the course on the ground. In the more congested areas, some of the smaller features are not included on the chart. If confused, hold the heading. If a turn is made away from the heading, it will be easy to become lost.

Roads shown on the chart are primarily the well-traveled roads or those most apparent when viewed from the air. New roads and structures are constantly being built, and may not be shown on the chart until the next chart is issued. Some structures, such as antennas may be difficult to see. Sometimes TV antennas are grouped together in an area near a town. They are supported by almost invisible guy wires. Never approach an area of antennas less than 500 feet above the tallest one. Most of the taller structures are marked with strobe lights to make them more visible to a pilot. However, some weather conditions or background lighting may make them difficult to see. Aeronautical charts display the best information available at the time of printing, but a pilot should be cautious for new structures or changes that have occurred since the chart was printed.

DEAD RECKONING

Dead reckoning is navigation solely by means of computations based on time, airspeed, distance, and direction. The products derived from these variables, when adjusted by windspeed and velocity, are heading and groundspeed. The predicted heading will guide the airplane along the intended path and the groundspeed will establish the time to arrive at each checkpoint and the destination. Except for flights over water, dead reckoning is usually used with pilotage for cross-country flying. The heading and groundspeed as calculated is constantly monitored and corrected by pilotage as observed from checkpoints.

THE WIND TRIANGLE OR VECTOR ANALYSIS

If there is no wind, the airplane's ground track will be the same as the heading and the groundspeed will be the same as the true airspeed. This condition rarely exists. A wind triangle, the pilot's version of vector analysis, is the basis of dead reckoning.

The wind triangle is a graphic explanation of the effect of wind upon flight. Groundspeed, heading, and time for any flight can be determined by using the wind triangle. It can be applied to the simplest kind of cross-country flight as well as the most complicated instrument flight. The experienced pilot becomes so familiar with the fundamental principles that estimates can be made which are adequate for visual flight without actually drawing the diagrams. The beginning student, however, needs to develop skill in constructing these diagrams as an aid to the complete understanding of wind effect. Either consciously or unconsciously, every good pilot thinks of the flight in terms of wind triangle.

If a flight is to be made on a course to the east, with a wind blowing from northeast, the airplane must be headed somewhat to the north of east to counteract drift. This can be represented by a diagram as shown in figure 14-17. Each line represents direction and speed. The long dotted line shows the direction the plane is heading, and its length represents the airspeed for 1 hour. The short dotted line at the right shows the wind direction, and its length represents the wind velocity

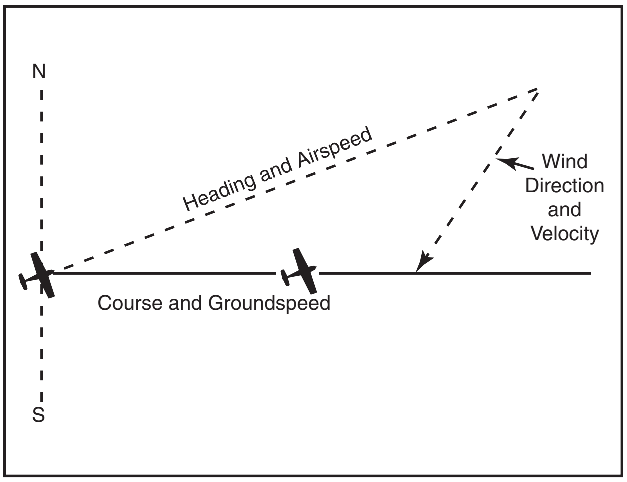


Figure 14-17. Principle of the wind triangle.

for 1 hour. The solid line shows the direction of the track, or the path of the airplane as measured over the Earth, and its length represents the distance traveled in 1 hour, or the groundspeed.

In actual practice, the triangle illustrated in figure 14-17 is not drawn; instead, construct a similar triangle as shown by the black lines in figure 14-18, which is explained in the following example.

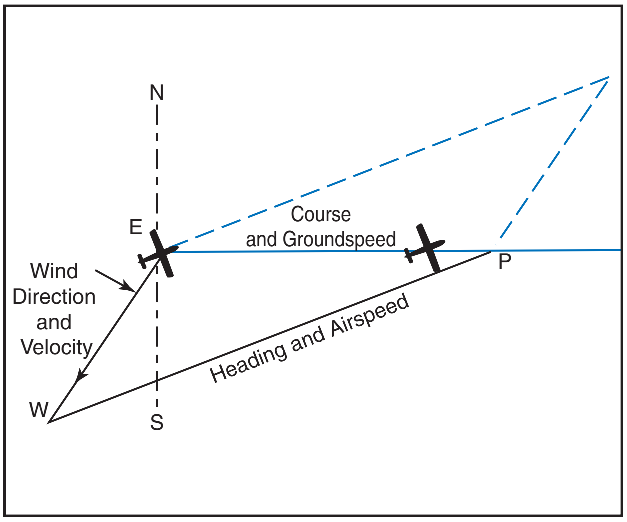


Figure 14-18. The wind triangle as is drawn in navigation practice. Dashed lines show the triangle as drawn in figure 14-17.

Suppose a flight is to be flown from E to P. Draw a line on the aeronautical chart connecting these two points; measure its direction with a protractor, or plotter, in reference to a meridian. This is the true course, which in this example is assumed to be 090° (east). From the National Weather Service, it is learned that the wind at the altitude of the intended flight is 40 knots from the northeast (045°). Since the National Weather Service reports the windspeed in knots, if the true airspeed of the airplane is 120 knots, there is no need to convert speeds from knots to miles per hour or vice versa.

Now on a plain sheet of paper draw a vertical line representing north and south. (The various steps are shown in figure 14-19.)

Place the protractor with the base resting on the vertical line and the curved edge facing east. At the center point of the base, make a dot labeled "E" (point of departure), and at the curved edge, make a dot at 90° (indicating the direction of the true course) and another at 45° (indicating wind direction).

With the ruler, draw the true course line from E, extending it somewhat beyond the dot by 90°, and labeling it "TC 090°."

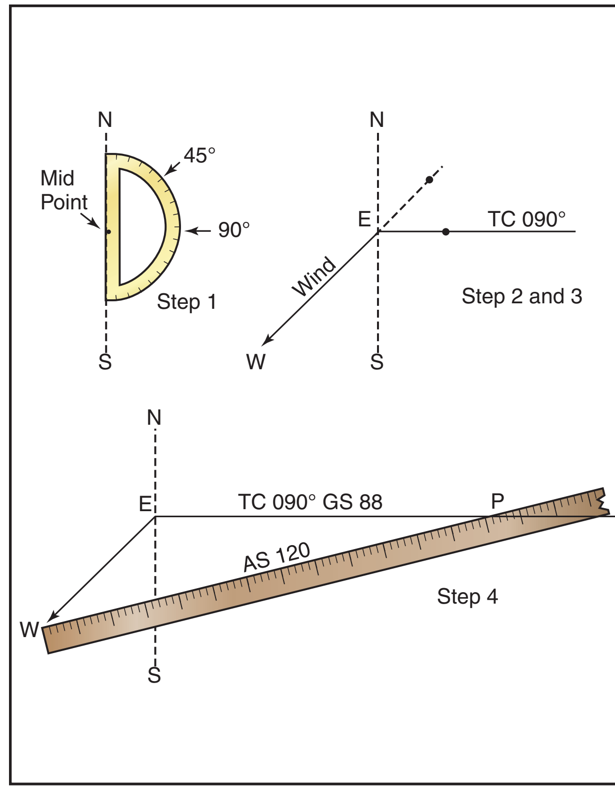


Figure 14-19. Steps in drawing the wind triangle.

Next, align the ruler with E and the dot at 45°, and draw the wind arrow from E, not toward 045°, but downwind in the direction the wind is blowing, making it 40 units long, to correspond with the wind velocity of 40 knots. Identify this line as the wind line by placing the letter "W" at the end to show the wind direction. Finally, measure 120 units on the ruler to represent the airspeed, making a dot on the ruler at this point. The units used may be of any convenient scale or value (such as $^{1}/_{4}$ inch = 10 knots), but once selected, the same scale must be used for each of the linear movements involved. Then place the ruler so that the end is on the arrowhead (W) and the 120-knot dot intercepts the true course line. Draw the line and label it "AS 120." The point "P" placed at the intersection represents the position of the airplane at the end of 1 hour. The diagram is now complete.

The distance flown in 1 hour (groundspeed) is measured as the numbers of units on the true course line (88 nautical miles per hour or 88 knots).

The true heading necessary to offset drift is indicated by the direction of the airspeed line, which can be determined in one of two ways:

- By placing the straight side of the protractor along the north-south line, with its center point at the intersection of the airspeed line and north-south line, read the true heading directly in degrees (076°). [Figure 14-20]

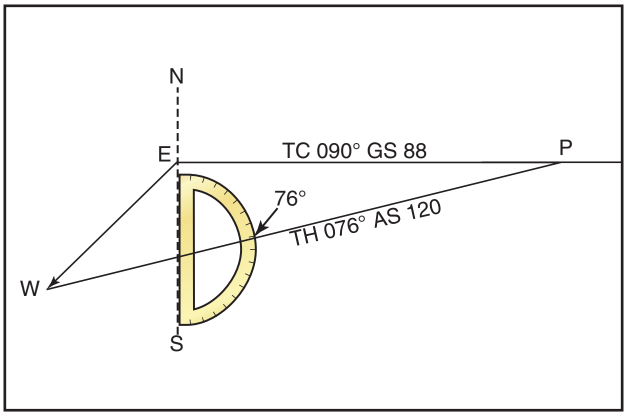


Figure 14-20. Finding true heading by direct measurement.

- By placing the straight side of the protractor along the true course line, with its center at P, read the angle between the true course and the airspeed line. This is the wind correction angle (WCA) which must be applied to the true course to obtain the true heading. If the wind blows from the right of true course, the angle will be added; if from the left, it will be subtracted. In the example given, the WCA is 14° and the wind is from the left; therefore, subtract 14° from true course of 090°, making the true heading 076°. [Figure 14-21]

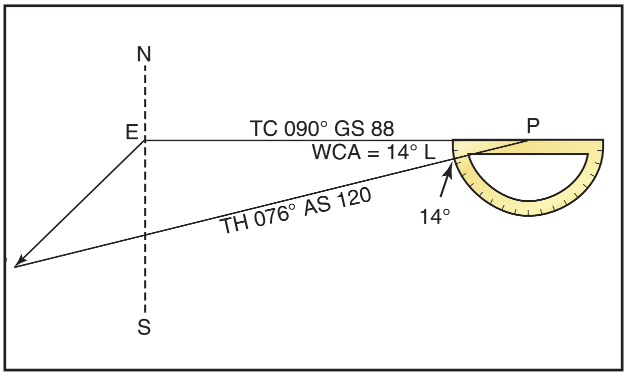


Figure 14-21. Finding true heading by the wind correction angle.

After obtaining the true heading, apply the correction for magnetic variation to obtain magnetic heading, and the correction for compass deviation to obtain a compass heading. The compass heading can be used to fly to the destination by dead reckoning.

To determine the time and fuel required for the flight, first find the distance to destination by measuring the length of the course line drawn on the aeronautical chart (using the appropriate scale at the bottom of the chart). If the distance measures 220 NM, divide by the groundspeed of 88 knots, which gives 2.5 hours or (2:30), as the time required. If fuel consumption is 8 gallons an hour, 8 x 2.5 or about 20 gallons will be used. Briefly summarized, the steps in obtaining flight information are as follows:

- **TRUE COURSE—**Direction of the line connecting two desired points, drawn on the chart and measured clockwise in degrees from true north on the mid-meridian.
- **WIND CORRECTION ANGLE—**Determined from the wind triangle. (Added to TC if the wind is from the right; subtract if wind is from the left.)
- **TRUE HEADING—**The direction measured in degrees clockwise from true north, in which the nose of the plane should point to make good the desired course.
- **VARIATION—**Obtained from the isogonic line on the chart. (Added to TH if west; subtract if east.)
- **MAGNETIC HEADING—**An intermediate step in the conversion. (Obtained by applying variation to true heading.)
- **DEVIATION—**Obtained from the deviation card on the airplane. (Added to MH or subtracted from, as indicated.)
- **COMPASS HEADING—**The reading on the compass (found by applying deviation to MH) which will be followed to make good the desired course.
- **TOTAL DISTANCE—**Obtained by measuring the length of the TC line on the chart (using the scale at the bottom of the chart).
- **GROUNDSPEED—**Obtained by measuring the length of the TC line on the wind triangle (using the scale employed for drawing the diagram).
- **ESTIMATED TIME EN ROUTE (ETE)—**Total distance divided by groundspeed.
- **FUEL RATE—**Predetermined gallons per hour used at cruising speed.

NOTE: Additional fuel for adequate reserve should be added as a safety measure.

FLIGHT PLANNING

Title 14 of the Code of Federal Regulations (14 CFR) part 91 states, in part, that before beginning a flight, the pilot in command of an aircraft shall become familiar with all available information concerning that flight. For flights not in the vicinity of an airport, this must include information on available current weather reports and forecasts, fuel requirements, alternatives available if the planned flight cannot be completed, and any known traffic delays of which the pilot in command has been advised by air traffic control (ATC).

ASSEMBLING NECESSARY MATERIAL

The pilot should collect the necessary material well before the flight. An appropriate current sectional chart and charts for areas adjoining the flight route should be among this material if the route of flight is near the border of a chart.

Additional equipment should include a flight computer or electronic calculator, plotter, and any other item appropriate to the particular flight—for example, if a night flight is to be undertaken, carry a flashlight; if a flight is over desert country, carry a supply of water and other necessities.

WEATHER CHECK

It may be wise to check the weather before continuing with other aspects of flight planning to see, first of all, if the flight is feasible and, if it is, which route is best. Chapter 11 on weather discusses obtaining a weather briefing.

USE OF THE AIRPORT/FACILITY DIRECTORY

Study available information about each airport at which a landing is intended. This should include a study of the *Notices to Airmen* (NOTAMs) and the *Airport/Facility Directory.* [Figure 14-22] This includes location, elevation, runway and lighting facilities, available services, availability of aeronautical advisory station frequency (UNICOM), types of fuel available (use to decide on refueling stops), AFSS/FSS located on the airport, control tower and ground control frequencies, traffic information, remarks, and other pertinent information. The NOTAMs, issued every 28 days, should be checked for additional information on hazardous conditions or changes that have been made since issuance of the *Airport/Facility Directory*.

The sectional chart bulletin subsection should be checked for major changes that have occurred since the last publication date of each sectional chart being used. Remember, the chart may be up to 6 months old. The effective date of the chart appears at the top of the front of the chart.

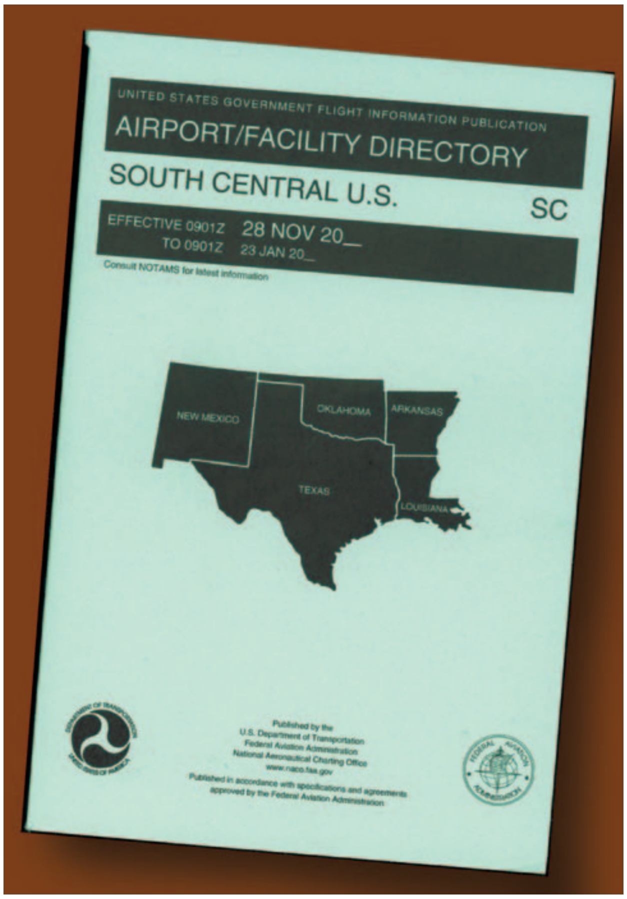


Figure 14-22. Airport Facility Directory.

The *Airport/Facility Directory* will generally have the latest information pertaining to such matters and should be used in preference to the information on the back of the chart, if there are differences.

AIRPLANE FLIGHT MANUAL OR PILOT'S OPERATING HANDBOOK

The Airplane Flight Manual or Pilot's Operating Handbook (AFM/POH) should be checked to determine the proper loading of the airplane (weight and balance data). The weight of the usable fuel and drainable oil aboard must be known. Also, check the weight of the passengers, the weight of all baggage to be carried, and the empty weight of the airplane to be sure that the total weight does not exceed the maximum allowable. The distribution of the load must be known to tell if the resulting center of gravity is within limits. Be sure to use the latest weight and balance information in the FAA-approved Airplane Flight Manual or other permanent airplane records, as appropriate, to obtain empty weight and empty weight center-of-gravity information.

Determine the takeoff and landing distances from the appropriate charts, based on the calculated load, elevation of the airport, and temperature; then compare these distances with the amount of runway available. Remember, the heavier the load and the higher the elevation, temperature, or humidity, the longer the takeoff roll and landing roll and the lower the rate of climb.

Check the fuel consumption charts to determine the rate of fuel consumption at the estimated flight altitude and power settings. Calculate the rate of fuel consumption, and then compare it with the estimated time for the flight so that refueling points along the route can be included in the plan.

CHARTING THE COURSE

Once the weather has been checked and some preliminary planning done, it is time to chart the course and determine the data needed to accomplish the flight. The following sections will provide a logical sequence to follow in charting the course, filling out a flight log, and filing a flight plan. In the following example, a trip is planned based on the following data and the sectional chart excerpt in figure 14-23.

Route of flight: Chickasha Airport direct to Guthrie Airport

- True Airspeed (TAS)..............................115 knots
- Winds Aloft....................................360° at 10 knots
- Usable fuel...38 gallons
- Fuel Rate..8 GPH
- Deviation...+2°

STEPS IN CHARTING THE COURSE

The following is a suggested sequence for arriving at the pertinent information for the trip. As information is determined, it may be noted as illustrated in the example of a flight log in figure 14-24. Where calculations are required, the pilot may use a mathematical formula or a manual or electronic flight computer. If unfamiliar with how to use a manual or electronic computer competently, it would be advantageous to read the operation manual and work several practice problems at this point.

First draw a line from Chickasha Airport (point A) directly to Guthrie Airport (point F). The course line should begin at the center of the airport of departure and end at the center of the destination airport. If the route is direct, the course line will consist of a single straight line. If the route is not direct, it will consist of two or more straight line segments—for example, a VOR station which is off the direct route, but which will make navigating easier, may be chosen (radio navigation is discussed later in this chapter).

Appropriate checkpoints should be selected along the route and noted in some way. These should be easy-to-locate points such as large towns, large lakes and rivers, or combinations of recognizable points such as towns with an airport, towns with a network of highways, and railroads entering and departing. Normally, choose only towns indicated by splashes of yellow on the chart. Do not choose towns represented by a small circle—these may turn out to be only a half-dozen houses. (In isolated areas, however, towns represented by a small circle can be prominent checkpoints.) For this trip, four checkpoints have been selected. Checkpoint 1 consists of a tower located east of the course and can be further identified by the highway and railroad track, which almost parallels the course at this point. Checkpoint 2 is the obstruction just to the west of the course and can be further identified by Will Rogers Airport which is directly to the east. Checkpoint 3 is Wiley Post Airport, which the airplane should fly directly over. Checkpoint 4 is a private non-surfaced airport to the west of the course and can be further identified by the railroad track and highway to the east of the course.

The course and areas on either side of the planned route should be checked to determine if there is any type of airspace with which the pilot should be concerned or which has special operational requirements. For this trip, it should be noted that the course will pass through a segment of the Class C airspace surrounding Will Rogers Airport where the floor of the airspace is 2,500 feet mean sea level (MSL) and the ceiling is 5,300 feet MSL (point B). Also, there is Class D airspace from the surface to 3,800 feet MSL surrounding Wiley Post Airport (point C) during the time the control tower is in operation.

Study the terrain and obstructions along the route. This is necessary to determine the highest and lowest elevations as well as the highest obstruction to be encountered so that an appropriate altitude which will conform to part 91 regulations can be selected. If the flight is to be flown at an altitude more than 3,000 feet above the terrain, conformance to the cruising altitude appropriate to the direction of flight is required. Check the route for particularly rugged terrain so it can be avoided. Areas where a takeoff or landing will be made should be carefully checked for tall obstructions. TV transmitting towers may extend to altitudes over 1,500 feet above the surrounding terrain. It is essential that pilots be aware of their presence and location. For this trip, it should be noted that the tallest obstruction is part of a series of antennas with a height of 2,749 feet MSL (point D). The highest elevation should be located in the northeast quadrant and is 2,900 feet MSL (point E).

Since the wind is no factor and it is desirable and within the airplane's capability to fly above the Class C and D airspace to be encountered, an altitude of 5,500 feet MSL will be chosen. This altitude also gives adequate clearance of all obstructions as well as conforms to the part 91 requirement to fly at an altitude of odd thousand plus 500 feet when on a magnetic course between 0 and 179°.

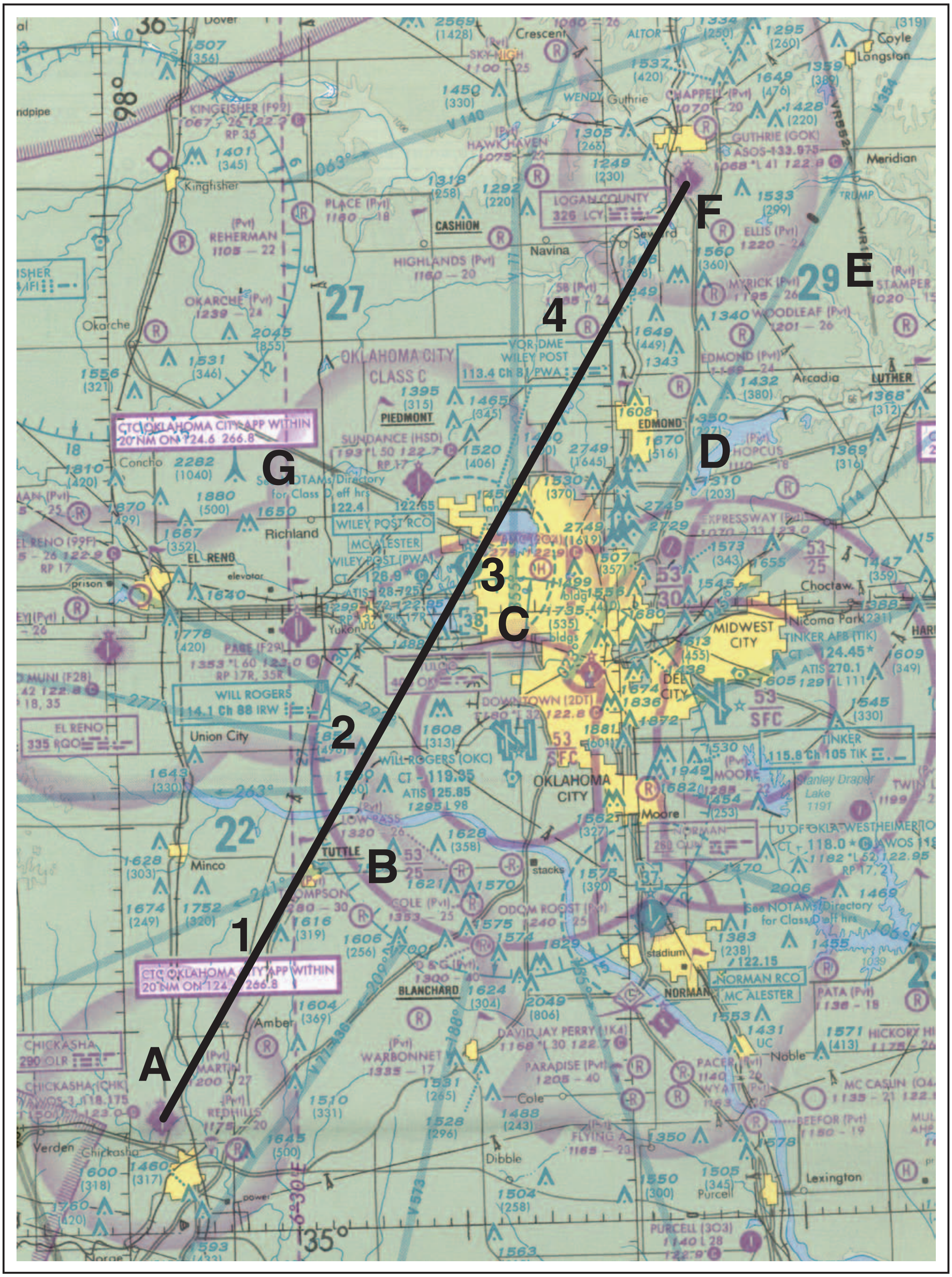


Figure 14-23. Sectional chart excerpt.

Next, the pilot should measure the total distance of the course as well as the distance between checkpoints. The total distance is 53 NM and the distance between checkpoints is as noted on the flight log in figure 14-24.

After determining the distance, the true course should be measured. If using a plotter, follow the directions on the plotter. The true course is 031°. Once the true heading is established, the pilot can determine the compass heading. This is done by following the formula given earlier in this chapter. The formula is:

TC ± WCA = TH ± VAR = MH ± DEV = CH

The wind correction angle can be determined by using a manual or electronic flight computer. Using a wind of 360° at 10 knots, it is determined the WCA is 3° left. This is subtracted from the TC making the TH 28°. Next, the pilot should locate the isogonic line closest to the route of the flight to determine variation. Point G in figure 14-23 shows the variation to be 6° 30′E (rounded to 7°E), which means it should be subtracted from the TH, giving an MH of 21°. Next, add 2° to the MH for the deviation correction. This gives the pilot the compass heading which is 23°.

Next, the groundspeed should be determined. This can be done using a manual or electronic calculator. It is determined the GS is 106 knots. Based on this information, the total trip time, as well as time between checkpoints, and the fuel burned can be determined. These calculations can be done mathematically or by using a manual or electronic calculator.

For this trip, the GS is 106 knots and the total time is 35 minutes (30 minutes plus 5 minutes for climb) with a fuel burn of 4.7 gallons. Refer to the flight log in figure 14-24 for the time between checkpoints.

As the trip progresses, the pilot can note headings and time and make adjustments in heading, groundspeed, and time.

FILING A VFR FLIGHT PLAN

Filing a flight plan is not required by regulations; however, it is a good operating practice, since the information contained in the flight plan can be used in search and rescue in the event of an emergency.

Flight plans can be filed in the air by radio, but it is best to file a flight plan either in person at the FSS or by phone just before departing. After takeoff, contact the FSS by radio and give them the takeoff time so the flight plan can be activated.

PILOT'S PLANNING SHEET

PLANE IDENTIFICATION N123DB **DATE**

COURSE	TC	WIND		WCA	TH	VAR	MH	DEV	CH	TOTAL MILES	GS	TOTAL TIME	FUEL RATE	TOTAL FUEL
		KNOTS	FROM	R+ L-		W+ E-								
From: Chickasha To: Guthrie	031°	10	360°	3° L	28	7° E	21°	+2°	23	53	106kts	35 min	8 GPH	38 gal
From: To:														

VISUAL FLIGHT LOG

TIME OF DEPARTURE	NAVIGATION AIDS	COURSE	DISTANCE	ELAPSED TIME	GS	CH	REMARKS
POINT OF DEPARTURE Chickasha Airport	NAVAID IDENT. FREQ.	TO / FROM	POINT TO POINT / CUMULATIVE	ESTIMATED / ACTUAL	ESTIMATED / ACTUAL	ESTIMATED / ACTUAL	WEATHER AIRSPACE ETC.
CHECKPOINTS #1			11 NM	6 MIN +5	106 kts	023°	
#2			10NM 21 NM	6 MIN	106 kts	023°	
#3			10.5 NM 31.5 NM	6 MIN	106 kts	023°	
#4			13 NM 44.5 NM	7 MIN	106 kts	023°	
DESTINATION Guthrie Airport			8.5 NM 53 NM	5 MIN			

Figure 14-24. Pilot's planning sheet and visual flight log.

When a VFR flight plan is filed, it will be held by the FSS until 1 hour after the proposed departure time and then canceled unless: the actual departure time is received; or a revised proposed departure time is received; or at the time of filing, the FSS is informed that the proposed departure time will be met, but actual time cannot be given because of inadequate communication. The FSS specialist who accepts the flight plan will not inform the pilot of this procedure, however.

Figure 14-25 shows the flight plan form a pilot files with the Flight Service Station. When filing a flight plan by telephone or radio, give the information in the order of the numbered spaces. This enables the FSS specialist to copy the information more efficiently. Most of the spaces are either self-explanatory or nonapplicable to the VFR flight plan (such as item 13). However, some spaces may need explanation.

Item 3 asks for the airplane type and special equipment. An example would be C-150/X, which means the airplane has no transponder. A listing of special equipment codes is listed in the *Aeronautical Information Manual* (AIM).

Item 6 asks for the proposed departure time in Universal Coordinated Time (indicated by the "Z").

Item 7 asks for the cruising altitude. Normally, "VFR" can be entered in this block, since the pilot will choose a cruising altitude to conform to FAA regulations.

Item 8 asks for the route of flight. If the flight is to be direct, enter the word "direct;" if not, enter the actual route to be followed such as via certain towns or navigation aids.

Item 10 asks for the estimated time en route. In the sample flight plan, 5 minutes was added to the total time to allow for the climb.

Item 12 asks for the fuel on board in hours and minutes. This is determined by dividing the total usable fuel aboard in gallons by the estimated rate of fuel consumption in gallons.

Remember, there is every advantage in filing a flight plan; but do not forget to close the flight plan on arrival. Do this by telephone with the nearest FSS, if possible, to avoid radio congestion.

RADIO NAVIGATION

Advances in navigational radio receivers installed in airplanes, the development of aeronautical charts which show the exact location of ground transmitting stations and their frequencies, along with refined cockpit instrumentation make it possible for pilots to navigate with precision to almost any point desired. Although precision in navigation is obtainable through the proper use of this equipment, beginning pilots should use this equipment to supplement navigation by visual reference to the ground (pilotage). This method provides the pilot with an effective safeguard against disorientation in the event of radio malfunction.

FLIGHT PLAN

1. TYPE	2. AIRCRAFT IDENTIFICATION	3. AIRCRAFT TYPE/ SPECIAL EQUIPMENT	4. TRUE AIRSPEED	5. DEPARTURE POINT	6. DEPARTURE TIME PROPOSED (Z)	6. DEPARTURE TIME ACTUAL (Z)	7. CRUISING ALTITUDE
X VFR IFR DVFR	N123DB	C150/X	115 KTS	CHICKASHA AIRPORT	1400Z		5500

8. ROUTE OF FLIGHT
Chickasha direct Guthrie

9. DESTINATION (Name of airport and city)	10. EST. TIME ENROUTE HOURS	10. EST. TIME ENROUTE MINUTES	11. REMARKS
Guthrie Airport Guthrie, OK		35	

12. FUEL ON BOARD HOURS	12. FUEL ON BOARD MINUTES	13. ALTERNATE AIRPORT(S)	14. PILOT'S NAME, ADDRESS & TELEPHONE NUMBER & AIRCRAFT HOME BASE	15. NUMBER ABOARD
4	45		Jane Smith Aero Air Oklahoma City, OK (405) 555-4149	1

16. COLOR OF AIRCRAFT	
Red/White	CLOSE VFR FLIGHT PLAN WITH McAlester FSS ON ARRIVAL

Figure 14-25. Flight plan form.

There are four radio navigation systems available for use for VFR navigation. These are:

VHF Omnidirectional Range (VOR)

Nondirectional Radiobeacon (NDB)

Long Range Navigation (LORAN-C)

Global Positioning System (GPS)

VERY HIGH FREQUENCY (VHF) OMNIDIRECTIONAL RANGE (VOR)

The VOR system is present in three slightly different navigation aids (NAVAIDs): VOR, VOR/DME, and VORTAC. By itself it is known as a VOR, and it provides magnetic bearing information to and from the station. When DME is also installed with a VOR, the NAVAID is referred to as a VOR/DME. When military tactical air navigation (TACAN) equipment is installed with a VOR, the NAVAID is known as a VORTAC. DME is always an integral part of a VORTAC. Regardless of the type of NAVAID utilized (VOR, VOR/DME or VORTAC), the VOR indicator behaves the same. Unless otherwise noted, in this section, VOR, VOR/DME and VORTAC NAVAIDs will all be referred to hereafter as VORs.

The word "omni" means all, and an omnidirectional range is a VHF radio transmitting ground station that projects straight line courses (radials) from the station in all directions. From a top view, it can be visualized as being similar to the spokes from the hub of a wheel. The distance VOR radials are projected depends upon the power output of the transmitter.

The course or radials projected from the station are referenced to magnetic north. Therefore, a radial is defined as a line of magnetic bearing extending outward from the VOR station. Radials are identified by numbers beginning with 001, which is 1° east of magnetic north, and progress in sequence through all the degrees of a circle until reaching 360. To aid in orientation, a compass rose reference to magnetic north is superimposed on aeronautical charts at the station location.

VOR ground stations transmit within a VHF frequency band of 108.0 – 117.95 MHz. Because the equipment is VHF, the signals transmitted are subject to line-of-sight restrictions. Therefore, its range varies in direct proportion to the altitude of receiving equipment. Generally, the reception range of the signals at an altitude of 1,000 feet above ground level (AGL) is about 40 to 45 miles. This distance increases with altitude. [Figure 14-26]

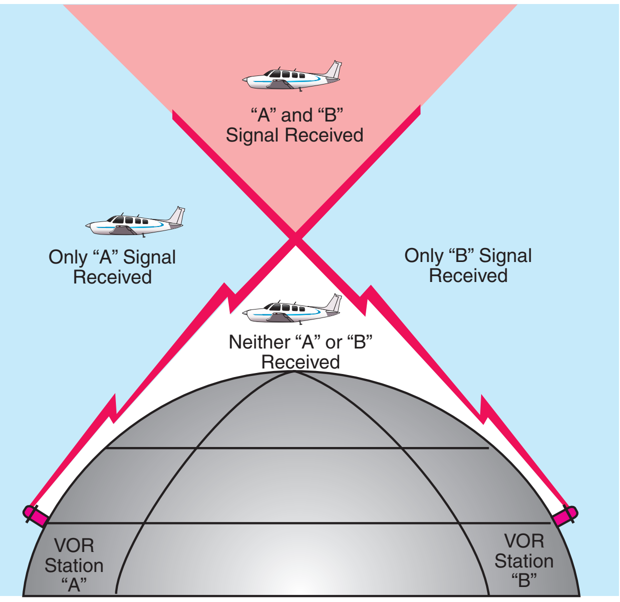


Figure 14-26. VHF transmissions follow a line-of-sight course.

VORs and VORTACs are classed according to operational use. There are three classes:

T (Terminal)

L (Low altitude)

H (High altitude)

The normal useful range for the various classes is shown in the following table:

VOR/VORTAC NAVAIDS

Normal Usable Altitudes and Radius Distances

Class	*Altitudes*	*Distance (Miles)*
T	12,000′ and below	25
L	Below 18,000′	40
H	Below 14,500′	40
H	Within the conterminous 48 states only, between 14,500 and 17,999′	100
H	18,000′ – FL 450	130
H	FL 450 – 60,000′	100

The useful range of certain facilities may be less than 50 miles. For further information concerning these restrictions, refer to the Comm/NAVAID Remarks in the *Airport/Facility Directory*.

The accuracy of course alignment of VOR radials is considered to be excellent. It is generally within plus or minus 1°. However, certain parts of the VOR receiver equipment deteriorate, and this affects its accuracy. This is particularly true at great distances from the VOR station. The best assurance of maintaining an accurate VOR receiver is periodic checks and calibrations. VOR accuracy checks are not a regulatory requirement for VFR flight. However, to assure accuracy of the equipment, these checks should be accomplished quite frequently along with a complete calibration each year. The following means are provided for pilots to check VOR accuracy:

- FAA VOR test facility (VOT);
- certified airborne checkpoints;
- certified ground checkpoints located on airport surfaces.

If dual VOR is installed in the airplane and tuned to the same VOR ground facility, the maximum permissible variation between the two indicated bearings is 4°.

A list of these checkpoints is published in the *Airport/Facility Directory*.

Basically, these checks consist of verifying that the VOR radials the airplane equipment receives are aligned with the radials the station transmits. There are not specific tolerances in VOR checks required for VFR flight. But as a guide to assure acceptable accuracy, the required IFR tolerances can be used which are ±4° for ground checks and ±6° for airborne checks. These checks can be performed by the pilot.

The VOR transmitting station can be positively identified by its Morse code identification or by a recorded voice identification which states the name of the station followed by the word "VOR." Many Flight Service Stations transmit voice messages on the same frequency that the VOR operates. Voice transmissions should not be relied upon to identify stations, because many FSSs remotely transmit over several omniranges, which have different names than the transmitting FSS. If the VOR is out of service for maintenance, the coded identification is removed and not transmitted. This serves to alert pilots that this station should not be used for navigation. VOR receivers are designed with an alarm flag to indicate when signal strength is inadequate to operate the navigational equipment. This happens if the airplane is too far from the VOR or the airplane is too low and therefore, is out of the line-of-sight of the transmitting signals.

USING THE VOR

In review, for VOR radio navigation, there are two components required: the ground transmitter and the airplane receiving equipment. The ground transmitter is located at a specific position on the ground and transmits on an assigned frequency. The airplane equipment includes a receiver with a tuning device and a VOR or omninavigation instrument. The navigation instrument consists of (1) an omnibearing selector (OBS) sometimes referred to as the course selector, (2) a course deviation indicator needle (Left-Right Needle), and (3) a TO-FROM indicator.

The course selector is an azimuth dial that can be rotated to select a desired radial or to determine the radial over which the airplane is flying. In addition, the magnetic course "TO" or "FROM" the station can be determined.

When the course selector is rotated, it moves the course deviation indicator (CDI) or needle to indicate the position of the radial relative to the airplane. If the course selector is rotated until the deviation needle is centered, the radial (magnetic course "FROM" the station) or its reciprocal (magnetic course "TO" the station) can be determined. The course deviation needle will also move to the right or left if the airplane is flown or drifting away from the radial which is set in the course selector.

By centering the needle, the course selector will indicate either the course "FROM" the station or the course "TO" the station. If the flag displays a "TO," the course shown on the course selector must be flown to the station.[Figure 14-27] If "FROM" is displayed and the course shown is followed, the airplane will be flown away from the station.

Figure 14-27. VOR indicator.

TRACKING WITH VOR

The following describes a step-by-step procedure to use when tracking to and from a VOR station. Figure 14-28 illustrates the discussion:

First, tune the VOR receiver to the frequency of the selected VOR station. For example: 115.0 to receive Bravo VOR. Next, check the identifiers to verify that the desired VOR is being received. As soon as the VOR is properly tuned, the course deviation needle will deflect either left or right; then rotate the azimuth dial to the course selector until the course deviation needle centers and the TO-FROM indicates "TO." If the needle centers with a "FROM" indication, the azimuth should be rotated 180° because, in this case, it is desired to fly "TO" the station. Now, turn the airplane to the heading indicated on the VOR azimuth dial or course selector. In this example 350°.

If a heading of 350° is maintained with a wind from the right as shown, the airplane will drift to the left of the intended track. As the airplane drifts off course, the VOR course deviation needle will gradually move to the right of center or indicate the direction of the desired radial or track.

To return to the desired radial, the airplane heading must be altered to the right. As the airplane returns to the desired track, the deviation needle will slowly return to center. When centered, the airplane will be on the desired radial and a left turn must be made toward, but not to the original heading of 350° because a wind drift correction must be established. The amount of correction depends upon the strength of the wind. If the wind velocity is unknown, a trial and error method can be used to find the correct heading. Assume, for this example, a 10° correction or a heading of 360° is maintained.

While maintaining a heading of 360°, assume that the course deviation begins to move to the left. This means that the wind correction of 10° is too great and the airplane is flying to the right of course. A slight turn to the left should be made to permit the airplane to return to the desired radial.

When the deviation needle centers, a small wind drift correction of 5° or a heading correction of 355° should be flown. If this correction is adequate, the airplane will remain on the radial. If not, small variation in heading should be made to keep the needle centered, and consequently keep the airplane on the radial.

As the VOR station is passed, the course deviation needle will fluctuate, then settle down, and the "TO" indication will change to "FROM." If the airplane passes to one side of the station, the needle will deflect in the direction of the station as the indicator changes to "FROM."

Generally, the same techniques apply when tracking outbound as those used for tracking inbound. If the intent is to fly over the station and track outbound on the reciprocal of the inbound radial, the course selector should not be changed. Corrections are made in the same manner to keep the needle centered. The only difference is that the omni will indicate "FROM."

If tracking outbound on a course other than the reciprocal of the inbound radial, this new course or radial must be set in the course selector and a turn made to intercept this course. After this course is reached, tracking procedures are the same as previously discussed.

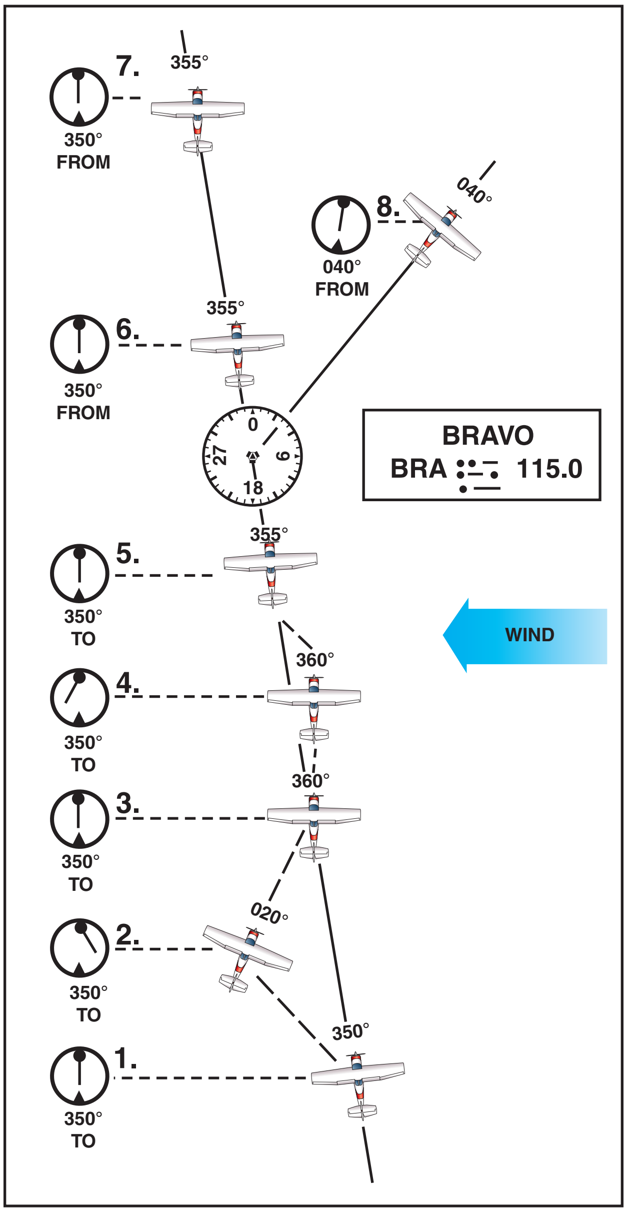


Figure 14-28. Tracking a radial in a crosswind.

TIPS ON USING THE VOR

- Positively identify the station by its code or voice identification.
- Keep in mind that VOR signals are "line-of-sight." A weak signal or no signal at all will be received if the airplane is too low or too far from the station.
- When navigating to a station, determine the inbound radial and use this radial. If the airplane drifts, do not reset the course selector, but correct for drift and fly a heading that will compensate for wind drift.
- If minor needle fluctuations occur, avoid changing headings immediately. Wait momentarily to see if the needle recenters; if it doesn't, then correct.
- When flying "TO" a station, always fly the selected course with a "TO" indication. When flying "FROM" a station, always fly the selected course with a "FROM" indication. If this is not done, the action of the course deviation needle will be reversed. To further explain this reverse action, if the airplane is flown toward a station with a "FROM" indication or away from a station with a "TO" indication, the course deviation needle will indicate in an opposite direction to that which it should. For example, if the airplane drifts to the right of a radial being flown, the needle will move to the right or point away from the radial. If the airplane drifts to the left of the radial being flown, the needle will move left or in the opposite direction of the radial.

DISTANCE MEASURING EQUIPMENT

Distance measuring equipment (DME) is an ultra high frequency (UHF) navigational aid present with VOR/DMEs and VORTACs. It measures, in nautical miles (NM), the slant range distance of an airplane from a VOR/DME or VORTAC (both hereafter referred to as a VORTAC). Although DME equipment is very popular, not all airplanes are DME equipped.

To utilize DME, the pilot should select, tune, and identify a VORTAC, as previously described. The DME receiver, utilizing what is called a "paired frequency" concept, automatically selects and tunes the UHF DME frequency associated with the VHF VORTAC frequency selected by the pilot. This process is entirely transparent to the pilot. After a brief pause, the DME display will show the slant range distance to or from the VORTAC. Slant range distance is the direct distance between the airplane and the VORTAC, and is therefore affected by airplane altitude. (Station passage directly over a VORTAC from an altitude of 6,076 feet above ground level (AGL) would show approximately 1.0 NM on the DME.) DME is a very useful adjunct to VOR navigation. A VOR radial alone merely gives line of position information. With DME, a pilot may precisely locate the airplane on that line (radial).

Most DME receivers also provide groundspeed and time-to-station modes of operation. The groundspeed is displayed in knots (NM per hour). The time-to-station mode displays the minutes remaining to VORTAC station passage, predicated upon the present groundspeed. Groundspeed and time-to-station information is only accurate when tracking directly to or from a VORTAC. DME receivers typically need a minute or two of stabilized flight directly to or from a VORTAC before displaying accurate groundspeed or time-to-station information.

Some DME installations have a hold feature that permits a DME signal to be retained from one VORTAC while the course indicator displays course deviation information from an ILS or another VORTAC.

VOR/DME RNAV

Area navigation (RNAV) permits electronic course guidance on any direct route between points established by the pilot. While RNAV is a generic term that applies to a variety of navigational aids, such as LORAN-C, GPS, and others, this section will deal with VOR/DME-based RNAV. VOR/DME RNAV is not a separate ground-based NAVAID, but a method of navigation using VOR/DME and VORTAC signals specially processed by the airplane's RNAV computer.

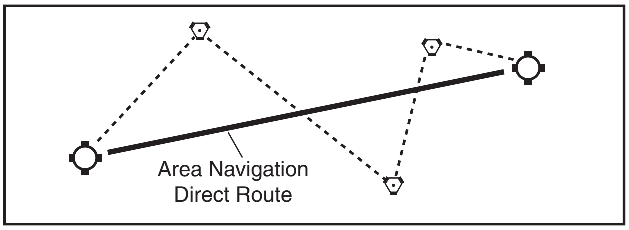


FIGURE 14-29. Flying an RNAV course.

[Figure 14-29] Note: In this section, the term "VORTAC" also includes VOR/DME NAVAIDs.

In its simplest form, VOR/DME RNAV allows the pilot to electronically move VORTACs around to more convenient locations. Once electronically relocated, they are referred to as waypoints. These waypoints are described as a combination of a selected radial and distance within the service volume of the VORTAC to be used. These waypoints allow a straight course to be flown between almost any origin and destination, without regard to the orientation of VORTACs or the existence of airways.

While the capabilities and methods of operation of VOR/DME RNAV units differ, there are basic principals of operation that are common to all. Pilots are urged to study the manufacturer's operating guide and receive instruction prior to the use of VOR/DME RNAV or any unfamiliar navigational system. Operational information and limitations should also be sought from placards and the supplement section of the Airplane Flight Manual and/or Pilot's Operating Handbook (AFM/POH).

VOR/DME-based RNAV units operate in at least three modes: VOR, En Route, and Approach. A fourth mode, VOR Parallel, may also be found on some models. The units need both VOR and DME signals to operate in any RNAV mode. If the NAVAID selected is a VOR without DME, RNAV mode will not function.

In the VOR (or non-RNAV) mode, the unit simply functions as a VOR receiver with DME capability. [Figure 14-30] The unit's display on the VOR indicator is conventional in all respects. For operation on established airways or any other ordinary VOR navigation, the VOR mode is used.

FIGURE 14-30. RNAV controls.

To utilize the unit's RNAV capability, the pilot selects and establishes a waypoint or a series of waypoints to define a course. To operate in any RNAV mode, the unit needs both radial and distance signals; therefore, a VORTAC (or VOR/DME) needs to be selected as a NAVAID. To establish a waypoint, a point somewhere within the service range of a VORTAC is defined on the basis of radial and distance. Once the waypoint is entered into the unit and the RNAV En Route mode is selected, the CDI will display course guidance to the waypoint, not the original VORTAC. DME will also display distance to the waypoint. Many units have the capability to store several waypoints, allowing them to be programmed prior to flight, if desired, and called up in flight.

RNAV waypoints are entered into the unit in magnetic bearings (radials) of degrees and tenths (i.e., 275.5°) and distances in nautical miles and tenths (i.e., 25.2 NM). When plotting RNAV waypoints on an aeronautical chart, pilots will find it difficult to measure to that level of accuracy, and in practical application, it is rarely necessary. A number of flight planning publications publish airport coordinates and waypoints with this precision and the unit will accept those figures. There is a subtle, but important difference in CDI operation and display in the RNAV modes.

In the RNAV modes, course deviation is displayed in terms of linear deviation. In the RNAV En Route mode, maximum deflection of the CDI typically represents 5 NM on either side of the selected course, without regard to distance from the waypoint. In the RNAV Approach mode, maximum deflection of the CDI typically represents 1 $^{1}/_{4}$ NM on either side of the selected course. There is no increase in CDI sensitivity as the airplane approaches a waypoint in RNAV mode.

The RNAV Approach mode is used for instrument approaches. Its narrow scale width (one-quarter of the En Route mode) permits very precise tracking to or from the selected waypoint. In visual flight rules (VFR) cross-country navigation, tracking a course in the Approach mode is not desirable because it requires a great deal of attention and soon becomes tedious.

A fourth, lesser-used mode on some units is the VOR Parallel mode. This permits the CDI to display linear (not angular) deviation as the airplane tracks to and from VORTACs. It derives its name from permitting the pilot to offset (or parallel) a selected course or airway at a fixed distance of the pilot's choosing, if desired. The VOR Parallel mode has the same effect as placing a waypoint directly over an existing VORTAC. Some pilots select the VOR Parallel mode when utilizing the navigation (NAV) tracking function of their autopilot for smoother course following near the VORTAC.

Confusion is possible when navigating an airplane with VOR/DME-based RNAV, and it is essential that the pilot become familiar with the equipment installed. It is not unknown for pilots to operate inadvertently in one of the RNAV modes when the operation was not intended by overlooking switch positions or annunciators. The reverse has also occurred with a pilot neglecting to place the unit into one of the RNAV modes by overlooking switch positions or annunciators. As always, the prudent pilot is not only familiar with the equipment used, but never places complete reliance in just one method of navigation when others are available for cross-check.

AUTOMATIC DIRECTION FINDER

Many general aviation-type airplanes are equipped with automatic direction finder (ADF) radio receiving equipment. To navigate using the ADF, the pilot tunes the receiving equipment to a ground station known as a NONDIRECTIONAL RADIOBEACON (NDB). The NDB stations normally operate in a low or medium frequency band of 200 to 415 kHz. The frequencies are readily available on aeronautical charts or in the *Airport/Facility Directory*.

All radiobeacons except compass locators transmit a continuous three-letter identification in code except during voice transmissions. A compass locator, which is associated with an Instrument Landing System, transmits a two-letter identification.

Standard broadcast stations can also be used in conjunction with ADF. Positive identification of all radio stations is extremely important and this is particularly true when using standard broadcast stations for navigation.

Nondirectional radiobeacons have one advantage over the VOR. This advantage is that low or medium frequencies are not affected by line-of-sight. The signals follow the curvature of the Earth; therefore, if the airplane is within the range of the station, the signals can be received regardless of altitude.

The following table gives the class of NDB stations, their power, and usable range:

NONDIRECTIONAL RADIOBEACON (NDB)
(Usable Radius Distances for All Altitudes)

Class	*Power(Watts)*	*Distance (Miles)*
Compass Locator	Under 25	15
MH	Under 50	25
H	50 – 1999	*50
HH	2000 or more	75

*Service range of individual facilities may be less than 50 miles.

One of the disadvantages that should be considered when using low frequency for navigation is that low-frequency signals are very susceptible to electrical disturbances, such as lightning. These disturbances create excessive static, needle deviations, and signal fades. There may be interference from distant stations. Pilots should know the conditions under which these disturbances can occur so they can be more alert to possible interference when using the ADF.

Basically, the ADF airplane equipment consists of a tuner, which is used to set the desired station frequency, and the navigational display.

The navigational display consists of a dial upon which the azimuth is printed, and a needle which rotates around the dial and points to the station to which the receiver is tuned.

Some of the ADF dials can be rotated so as to align the azimuth with the airplane heading; others are fixed with 0° representing the nose of the airplane, and 180° representing the tail. Only the fixed azimuth dial will be discussed in this handbook. [Figure 14-31]

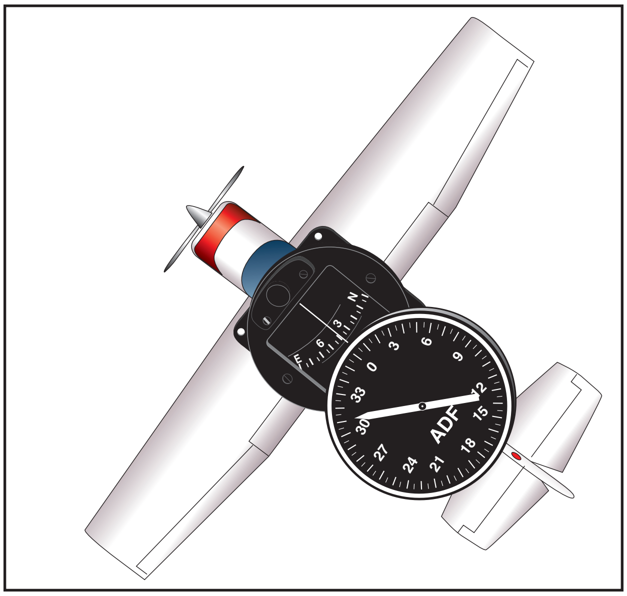


Figure 14-31. ADF with fixed azimuth and magnetic compass.

Figure 14-32 illustrates the following terms that are used with the ADF and should be understood by the pilot.

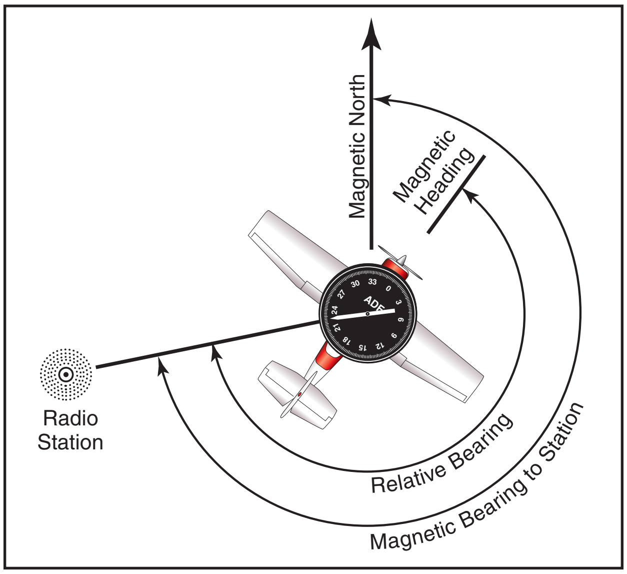


Figure 14-32. ADF terms.

Relative Bearing—is the value to which the indicator (needle) points on the azimuth dial. When using a fixed dial, this number is relative to the nose of the airplane and is the angle measured clockwise from the nose of the airplane to a line drawn from the airplane to the station.

Magnetic Bearing—"TO" the station is the angle formed by a line drawn from the airplane to the station and a line drawn from the airplane to magnetic north. The magnetic bearing to the station can be determined by adding the relative bearing to the magnetic heading of the airplane. For example, if the relative bearing is 060° and the magnetic heading is 130°, the magnetic bearing to the station is

060° plus 130° or 190°. This means that in still air a magnetic heading of approximately 190° would be flown to the station. If the total is greater than 360°, subtract 360° from the total to obtain the magnetic bearing to the station. For example, if the relative bearing is 270° and magnetic heading is 300°, 360° is subtracted from the total, or 570° – 360° = 210°, which is the magnetic bearing to the station.

To determine the magnetic bearing "FROM" the station, 180° is added to or subtracted from the magnetic bearing to the station. This is the reciprocal bearing and is used when plotting position fixes.

Keep in mind that the needle of fixed azimuth points to the station in relation to the nose of the airplane. If the needle is deflected 30° to the left or a relative bearing of 330°, this means that the station is located 30° left. If the airplane is turned left 30°, the needle will move to the right 30° and indicate a relative bearing of 0° or the airplane will be pointing toward the station. If the pilot continues flight toward the station keeping the needle on 0°, the procedure is called homing to the station. If a crosswind exists, the ADF needle will continue to drift away from zero. To keep the needle on zero, the airplane must be turned slightly resulting in a curved flightpath to the station. Homing to the station is a common procedure, but results in drifting downwind, thus lengthening the distance to the station.

Tracking to the station requires correcting for wind drift and results in maintaining flight along a straight track or bearing to the station. When the wind drift correction is established, the ADF needle will indicate the amount of correction to the right or left. For instance, if the magnetic bearing to the station is 340°, a correction for a left crosswind would result in a magnetic heading of 330°, and the ADF needle would indicate 10° to the right or a relative bearing of 010°. [Figure 14-33]

When tracking away from the station, wind corrections are made similar to tracking to the station, but the ADF needle points toward the tail of the airplane or the 180° position on the azimuth dial. Attempting to keep the ADF needle on the 180° position during winds results in the airplane flying a curved flight leading further and further from the desired track. To correct for wind when tracking outbound, correction should be made in the direction opposite of that in which the needle is pointing.

Although the ADF is not as popular as the VOR for radio navigation, with proper precautions and intelligent use, the ADF can be a valuable aid to navigation.

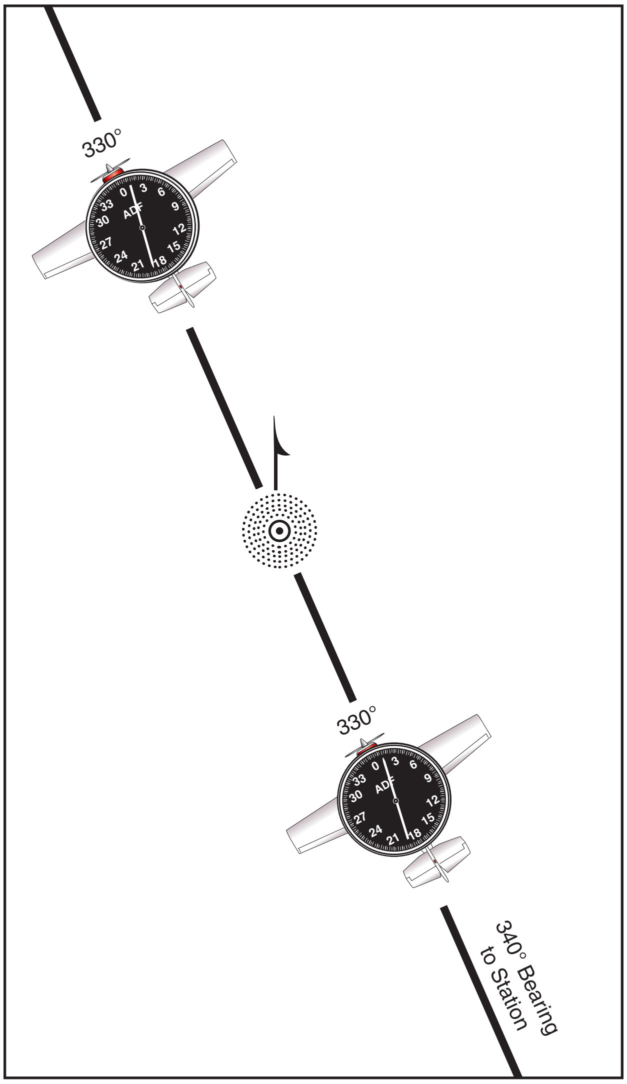


Figure 14-33. ADF tracking.

LORAN-C NAVIGATION

Long Range Navigation, version C (LORAN-C) is another form of RNAV, but one that operates from chains of transmitters broadcasting signals in the low frequency (LF) spectrum. World Aeronautical Chart (WAC), Sectional Charts, and VFR Terminal Area Charts do not show the presence of LORAN-C transmitters. Selection of a transmitter chain is either made automatically by the unit, or manually by the pilot using guidance information provided by the manufacturer. LORAN-C is a highly accurate, supplemental form of navigation typically installed as an adjunct to VOR and ADF equipment. Databases of airports, NAVAIDs, and air traffic control facilities are frequently features of LORAN-C receivers.

LORAN-C is an outgrowth of the original LORAN-A developed for navigation during World War II. The LORAN-C system is used extensively in maritime applications. It experienced a dramatic growth in popularity with pilots with the advent of the small, panel-mounted LORAN-C receivers available at relatively low cost. These units are frequently very sophisticated and capable, with a wide variety of navigational functions.

With high levels of LORAN-C sophistication and capability, a certain complexity in operation is an unfortunate necessity. Pilots are urged to read the operating handbooks and to consult the supplements section of the AFM/POH prior to utilizing LORAN-C for navigation. Many units offer so many features that the manufacturers often publish two different sets of instructions: (1) a brief operating guide and (2) in-depth operating manual.

While coverage is not global, LORAN-C signals are suitable for navigation in all of the conterminous United States, and parts of Canada and Alaska. Several foreign countries also operate their own LORAN-C systems. In the United States, the U.S. Coast Guard operates the LORAN-C system. LORAN-C system status is available from: USCG Navigation Center, Alexandria, VA (703) 313-5900.

LORAN-C absolute accuracy is excellent—position errors are typically less than .25 NM. Repeatable accuracy, or the ability to return to a waypoint previously visited, is even better. While LORAN-C is a form of RNAV, it differs significantly from VOR/DME-based RNAV. It operates in a 90 – 110 kHz frequency range and is based upon measurement of the difference in arrival times of pulses of radio frequency (RF) energy emitted by a chain of transmitters hundreds of miles apart.

Within any given chain of transmitters, there is a master station, and from three to five secondary stations. LORAN-C units must be able to receive at least a master and two secondary stations to provide navigational information. Unlike VOR/DME-based RNAV, where the pilot must select the appropriate VOR/DME or VORTAC frequency, there is not a frequency selection in LORAN-C. The most advanced units automatically select the optimum chain for navigation. Other units rely upon the pilot to select the appropriate chain with a manual entry.

After the LORAN-C receiver has been turned on, the unit must be initialized before it can be used for navigation. While this can be accomplished in flight, it is preferable to perform this task, which can take several minutes, on the ground. The methods for initialization are as varied as the number of different models of receivers. Some require pilot input during the process, such as verification or acknowledgment of the information displayed.

Most units contain databases of navigational information. Frequently, such databases contain not only airport and NAVAID locations, but also extensive airport, airspace, and ATC information. While the unit will operate with an expired database, the information should be current or verified to be correct prior to use. The pilot can update some databases, while others require removal from the airplane and the services of an avionics technician.

VFR navigation with LORAN-C can be as simple as telling the unit where the pilot wishes to go. The course guidance provided will be a great circle (shortest distance) route to the destination. Older units may need a destination entered in terms of latitude and longitude, but recent designs only need the identifier of the airport or NAVAID. The unit will also permit database storage and retrieval of pilot defined waypoints. LORAN-C signals follow the curvature of the Earth and are generally usable hundreds of miles from their transmitters.

The LORAN-C signal is subject to degradation from a variety of atmospheric disturbances. It is also susceptible to interference from static electricity buildup on the airframe and electrically “noisy” airframe equipment. Flight in precipitation or even dust clouds can cause occasional interference with navigational guidance from LORAN-C signals. To minimize these effects, static wicks and bonding straps should be installed and properly maintained.

LORAN-C navigation information is presented to the pilot in a variety of ways. All units have self-contained displays, and some elaborate units feature built-in moving map displays. Some installations can also drive an external moving map display, a conventional VOR indicator, or a horizontal situation indicator (HSI). Course deviation information is presented as a linear deviation from course—there is no increase in tracking sensitivity as the airplane approaches the waypoint or destination. Pilots must carefully observe placards, selector switch positions, and annunciator indications when utilizing LORAN-C because airplane installations can vary widely. The pilot’s familiarity with unit operation through AFM/POH supplements and operating guides cannot be overemphasized.

LORAN-C *Notices To Airmen* (NOTAMs) should be reviewed prior to relying on LORAN-C for navigation. LORAN-C NOTAMs will be issued to announce outages for specific chains and transmitters. Pilots may obtain LORAN-C NOTAMs from FSS briefers only upon request.

The prudent pilot will never rely solely on one means of navigation when others are available for backup and cross-check. Pilots should never become so dependent upon the extensive capabilities of LORAN-C that other methods of navigation are neglected.

GLOBAL POSITIONING SYSTEM

The global positioning system (GPS) is a satellite-based radio navigation system. Its RNAV guidance is worldwide in scope. There are no symbols for GPS on aeronautical charts as it is a space-based system with global coverage. Development of the system is underway so that GPS will be capable of providing the primary means of electronic navigation. Portable and yoke mounted units are proving to be very popular in addition to those permanently installed in the airplane. Extensive navigation databases are common features in airplane GPS receivers.

The GPS is a satellite radio navigation and time dissemination system developed and operated by the U.S. Department of Defense (DOD). Civilian interface and GPS system status is available from the U.S. Coast Guard.

It is not necessary to understand the technical aspects of GPS operation to use it in VFR/instrument flight rules (IFR) navigation. It does differ significantly from conventional, ground-based electronic navigation, and awareness of those differences is important. Awareness of equipment approvals and limitations is critical to the safety of flight. The GPS system is composed of three major elements:

1. The space segment is composed of a constellation of 26 satellites orbiting approximately 10,900 NM above the Earth. The operational satellites are often referred to as the GPS constellation. The satellites are not geosynchronous but instead orbit the Earth in periods of approximately 12 hours. Each satellite is equipped with highly stable atomic clocks and transmits a unique code and navigation message. Transmitting in the UHF range means that the signals are virtually unaffected by weather although they are subject to line-of-sight limitations. The satellites must be above the horizon (as seen by the receiver's antenna) to be usable for navigation.

2. The control segment consists of a master control station at Falcon AFB, Colorado Springs, CO, five monitor stations, and three ground antennas. The monitor stations and ground antennas are distributed around the Earth to allow continual monitoring and communications with the satellites. Updates and corrections to the navigational message broadcast by each satellite are uplinked to the satellites as they pass over the ground antennas.

3. The user segment consists of all components associated with the GPS receiver, ranging from portable, hand-held receivers to receivers permanently installed in the airplane. The receiver matches the satellite's coded signal by shifting its own identical code in a matching process to precisely measure the time of arrival. Knowing the speed the signal traveled (approximately 186,000 miles per second) and the exact broadcast time, the distance traveled by the signal can be inferred from its arrival time.

To solve for its location, the GPS receiver utilizes the signals of at least four of the best-positioned satellites to yield a three-dimensional fix (latitude, longitude, and altitude). A two-dimensional fix (latitude and longitude only) can be determined with as few as three satellites. GPS receivers have extensive databases. Databases are provided initially by the receiver manufacturer and updated by the manufacturer or a designated data agency.

A wide variety of GPS receivers with extensive navigation capabilities are available. Panel mounted units permanently installed in the airplane may be used for VFR and may also have certain IFR approvals. Portable hand-held and yoke mounted GPS receivers are also popular, although these are limited to VFR use. Not all GPS receivers on the market are suited for air navigation. Marine, recreational, and surveying units, for example, are not suitable for airplane use. As with LORAN-C receivers, GPS unit features and operating procedures vary widely. The pilot must be familiar with the manufacturer's operating guide. Placards, switch positions, and annunciators should be carefully observed.

Initialization of the unit will require several minutes and should be accomplished prior to flight. If the unit has not been operated for several months or if it has been moved to a significantly different location (by several hundred miles) while off, this may require several additional minutes. During initialization, the unit will make internal integrity checks, acquire satellite signals, and display the database revision date. While the unit will operate with an expired database, the database should be current, or verified to be correct, prior to relying on it for navigation.

VFR navigation with GPS can be as simple as selecting a destination (an airport, VOR, NDB, intersection, or pilot defined waypoint) and placing the unit in the navigation mode. Course guidance provided will be a great circle route (shortest distance) direct to the destination. Many units provide advisory information about special use airspace and minimum safe altitudes, along with extensive airport data, and ATC services and frequencies. Users having prior experience with LORAN-C receivers will note many similarities in the wealth of navigation information available, although the technical principles of operation are quite different.

All GPS receivers have integral (built into the unit) navigation displays and some feature integral moving map displays. Some panel-mounted units will drive a VOR indicator, HSI, or even an external moving map display. GPS course deviation is linear—there is not an increase in tracking sensitivity as the airplane approaches a waypoint. Pilots must carefully observe placards, selector switch positions, and annunciator indications when utilizing GPS as installations and approvals can vary widely.

The integral GPS navigation display (like most LORAN-C units) uses several additional navigational terms beyond those used in NDB and VOR navigation. Some of these terms, whose abbreviations vary among manufacturers, are shown below. The pilot should consult the manufacturer's operating guide for specific definitions.

NOTAMs should be reviewed prior to relying on GPS for navigation. GPS NOTAMs will be issued to announce outages for specific GPS satellites by pseudorandom noise code (PRN) and satellite vehicle number (SVN). Pilots may obtain GPS NOTAMs from FSS briefers only upon request.

When using any sophisticated and highly capable navigation system, such as LORAN-C or GPS, there is a strong temptation to rely almost exclusively on that unit, to the detriment of using other techniques of position keeping. The prudent pilot will never rely on one means of navigation when others are available for cross-check and backup.

LOST PROCEDURES

Getting lost in an airplane is a potentially dangerous situation especially when low on fuel. If a pilot becomes lost, there are some good common sense procedures to follow. If a town or city cannot be seen, the first thing to do is climb, being mindful of traffic and weather conditions. An increase in altitude increases radio and navigation reception range, and also increases radar coverage. If flying near a town or city, it might be possible to read the name of the town on a water tower.

If the airplane has a navigational radio, such as a VOR or ADF receiver, it can be possible to determine position by plotting an azimuth from two or more navigational facilities. If GPS is installed, or a pilot has a portable aviation GPS on board, it can be used to determine the position and the location of the nearest airport.

Communicate with any available facility using frequencies shown on the sectional chart. If contact is made with a controller, radar vectors may be offered. Other facilities may offer direction finding (DF) assistance. To use this procedure, the controller will request the pilot to hold down the transmit button for a few seconds and then release it. The controller may ask the pilot to change directions a few times and repeat the transmit procedure. This gives the controller enough information to plot the airplane position and then give vectors to a suitable landing site. If the situation becomes threatening, transmit the situation on the emergency frequency 121.5 MHz and set the transponder to 7700. Most facilities, and even airliners, monitor the emergency frequency.

FLIGHT DIVERSION

There will probably come a time when a pilot will not be able to make it to the planned destination. This can be the result of unpredicted weather conditions, a system malfunction, or poor preflight planning. In any case, the pilot will need to be able to safely and efficiently divert to an alternate destination. Before any cross-country flight, check the charts for airports or suitable landing areas along or near the route of flight. Also, check for navigational aids that can be used during a diversion.

Computing course, time, speed, and distance information in flight requires the same computations used during preflight planning. However, because of the limited cockpit space, and because attention must be divided between flying the airplane, making calculations, and scanning for other airplanes, take advantage of all possible shortcuts and rule-of-thumb computations.

When in flight, it is rarely practical to actually plot a course on a sectional chart and mark checkpoints and distances. Furthermore, because an alternate airport is usually not very far from your original course, actual plotting is seldom necessary.

A course to an alternate can be measured accurately with a protractor or plotter, but can also be measured with reasonable accuracy using a straightedge and the compass rose depicted around VOR stations. This approximation can be made on the basis of a radial from a nearby VOR or an airway that closely parallels the course to your alternate. However, remember that the magnetic heading associated with a VOR radial or printed airway is outbound from the station. To find the course TO the station, it may be necessary to determine the reciprocal of that heading. It is typically easier to navigate to an alternate airport that has a VOR or NDB facility on the field.

After selecting the most appropriate alternate, approximate the magnetic course to the alternate using a compass rose or airway on the sectional chart. If time permits, try to start the diversion over a prominent ground feature. However, in an emergency, divert promptly toward your alternate. To complete all plotting, measuring, and computations involved before diverting to the alternate may only aggravate an actual emergency.

Once established on course, note the time, and then use the winds aloft nearest to your diversion point to calculate a heading and groundspeed. Once a groundspeed has been calculated, determine a new arrival time and fuel consumption. Give priority to flying the airplane while dividing attention between navigation and planning. When determining an altitude to use while diverting, consider cloud heights, winds, terrain, and radio reception.

Chapter 15

Aeromedical Factors

As a pilot, it is important to stay aware of the mental and physical standards required for the type of flying done. This chapter provides information on medical certification and on aeromedical factors related to flying activities.

OBTAINING A MEDICAL CERTIFICATE

Most pilots must have a valid medical certificate to exercise the privileges of their airman certificates. Glider and free balloon pilots are not required to hold a medical certificate. Sport pilots may hold either a medical certificate or a valid state driver's license.

To acquire a medical certificate, an examination by an aviation medical examiner (AME), a physician with training in aviation medicine designated by the Civil Aerospace Medical Institute (CAMI), is required. There are three classes of medical certificates. The class of certificate needed depends on the type of flying the pilot plans to do.

A third-class medical is required for a private or recreational pilot certificate. It is valid for 3 years for those individuals who have not reached the age of 40; otherwise it is valid for 2 years. A commercial pilot certificate requires at least a second-class medical certificate, which is valid for 1 year. First-class medical certificates are required for airline transport pilots, and are valid for 6 months.

The standards are more rigorous for the higher classes of certificates. A pilot with a higher class medical certificate has met the requirements for the lower classes as well. Since the class of medical required applies only when exercising the privileges of the pilot certificate for which it is required, a first-class medical would be valid for 1 year if exercising the privileges of a commercial certificate, and 2 or 3 years, as appropriate, for exercising the privileges of a private or recreational certificate. The same applies for a second-class medical certificate. The standards for medical certification are contained in Title 14 of the Code of Federal Regulations (14 CFR) part 67, and the requirements for obtaining medical certificates are in 14 CFR part 61.

Students who have physical limitations, such as impaired vision, loss of a limb, or hearing impairment may be issued a medical certificate valid for "student pilot privileges only" while they are learning to fly. Pilots with disabilities may require special equipment installed in the airplane, such as hand controls for pilots with paraplegia. Some disabilities necessitate a limitation on the individual's certificate; for example, impaired hearing would require the limitation "not valid for flight requiring the use of radio." When all the knowledge, experience, and proficiency requirements have been met and a student can demonstrate the ability to operate the airplane with the normal level of safety, a "statement of demonstrated ability" (SODA) can be issued. This waiver or SODA is valid as long as their physical impairment does not worsen. Contact the local Flight Standards District Office (FSDO) for more information on this subject.

ENVIRONMENTAL AND HEALTH FACTORS AFFECTING PILOT PERFORMANCE

A number of health factors and physiological effects can be linked to flying. Some are minor, while others are important enough to require special attention to ensure safety of flight. In some cases, physiological factors can lead to in-flight emergencies. Some important medical factors that a pilot should be aware of include hypoxia, hyperventilation, middle ear and sinus problems, spatial disorientation, motion sickness, carbon monoxide poisoning, stress and fatigue, dehydration, and heatstroke. Other subjects include the effects of alcohol and drugs, anxiety, and excess nitrogen in the blood after scuba diving.

HYPOXIA

Hypoxia means "reduced oxygen" or "not enough oxygen." Although any tissue will die if deprived of oxygen long enough, usually the most concern is with getting enough oxygen to the brain, since it is particularly vulnerable to oxygen deprivation. Any reduction in mental function while flying can result in life-threatening errors. Hypoxia can be caused by several factors including an insufficient supply of oxygen, inadequate transportation of oxygen, or the inability of the body tissues to use oxygen. The forms of hypoxia are divided into four major groups based on their causes: hypoxic hypoxia, hypemic hypoxia, stagnant hypoxia, and histotoxic hypoxia.

HYPOXIC HYPOXIA

Hypoxic hypoxia is a result of insufficient oxygen available to the lungs. A blocked airway or drowning are obvious examples of how the lungs can be deprived of oxygen, but the reduction in partial pressure of oxygen at high altitude is an appropriate example for pilots. Although the percentage of oxygen in the atmosphere is constant, its partial pressure decreases proportionately as atmospheric pressure decreases. As the airplane ascends during flight, the percentage of each gas in the atmosphere remains the same, but there are fewer molecules available at the pressure required for them to pass between the membranes in the respiratory system. This decrease of oxygen molecules at sufficient pressure can lead to hypoxic hypoxia.

HYPEMIC HYPOXIA

This occurs when the blood is not able to take up and transport a sufficient amount of oxygen to the cells in the body. Hypemic means "not enough blood." This type of hypoxia is a result of oxygen deficiency in the blood, rather than a lack of inhaled oxygen, and can be caused by a variety of factors. It may be because there is not enough blood volume (due to severe bleeding), or may result from certain blood diseases, such as anemia. More often it is because hemoglobin, the actual blood molecule that transports oxygen, is chemically unable to bind oxygen molecules. The most common form of hypemic hypoxia is carbon monoxide poisoning. Hypemic hypoxia also can be caused by the loss of blood from a blood donation. Blood can take several weeks to return to normal following a donation. Although the effects of the blood loss are slight at ground level, there are risks when flying during this time.

STAGNANT HYPOXIA

Stagnant means "not flowing," and stagnant hypoxia results when the oxygen-rich blood in the lungs isn't moving, for one reason or another, to the tissues that need it. An arm or leg going to sleep because the blood flow has accidentally been shut off is one form of stagnant hypoxia. This kind of hypoxia can also result from shock, the heart failing to pump blood effectively, or a constricted artery. During flight, stagnant hypoxia can occur when pulling excessive positive Gs. Cold temperatures also can reduce circulation and decrease the blood supplied to extremities.

HISTOTOXIC HYPOXIA

The inability of the cells to effectively use oxygen is defined as histotoxic hypoxia. "Histo" refers to tissues or cells, and "toxic" means poison. In this case, plenty of oxygen is being transported to the cells that need it, but they are unable to make use of it. This impairment of cellular respiration can be caused by alcohol and other drugs, such as narcotics and poisons. Research has shown that drinking one ounce of alcohol can equate to about an additional 2,000 feet of physiological altitude.

SYMPTOMS OF HYPOXIA

High-altitude flying can place a pilot in danger of becoming hypoxic. Oxygen starvation causes the brain and other vital organs to become impaired. One particularly noteworthy attribute of the onset of hypoxia is the fact that the first symptoms are euphoria and a carefree feeling. With increased oxygen starvation, the extremities become less responsive and flying becomes less coordinated. The symptoms of hypoxia vary with the individual, but common symptoms include:

- Cyanosis (blue fingernails and lips)
- Headache
- Decreased reaction time
- Impaired judgment
- Euphoria
- Visual impairment
- Drowsiness
- Lightheaded or dizzy sensation
- Tingling in fingers and toes
- Numbness

As hypoxia worsens, the field of vision begins to narrow, and instrument interpretation can become difficult. Even with all these symptoms, the effects of hypoxia can cause a pilot to have a false sense of security and be deceived into believing that everything is normal. The treatment for hypoxia includes flying at lower altitudes and/or using supplemental oxygen.

All pilots are susceptible to the effects of oxygen starvation, regardless of physical endurance or acclimatization. When flying at high altitudes, it is paramount that oxygen be used to avoid the effects of hypoxia. The term "time of useful consciousness" describes the maximum time the pilot has to make rational, life-saving decisions and carry them out at a given altitude without supplemental oxygen. As altitude increases above 10,000 feet, the symptoms of hypoxia increase in severity, and the time of useful consciousness rapidly decreases. [Figure 15-1]

Altitude	Time of Useful Consciousness
45,000 feet MSL	9 to 15 seconds
40,000 feet MSL	15 to 20 seconds
35,000 feet MSL	30 to 60 seconds
30,000 feet MSL	1 to 2 minutes
28,000 feet MSL	2 1/2 to 3 minutes
25,000 feet MSL	3 to 5 minutes
22,000 feet MSL	5 to 10 minutes
20,000 feet MSL	30 minutes or more

Figure 15-1. Time of useful consciousness.

Since symptoms of hypoxia can be different for each individual, the ability to recognize hypoxia can be greatly improved by experiencing and witnessing the effects of it during an altitude chamber "flight." The Federal Aviation Administration (FAA) provides this opportunity through aviation physiology training, which is conducted at the FAA Civil Aerospace Medical Institute (CAMI) and at many military facilities across the United States. To attend the Physiological Training Program at CAMI, telephone (405) 954-4837 or write:

Mike Monroney Aeronautical Center
Airman Education Program
CAMI (AAM-400)
P.O. Box 25082
Oklahoma City, OK 73125

HYPERVENTILATION

Hyperventilation occurs when an individual is experiencing emotional stress, fright, or pain, and the breathing rate and depth increase, although the carbon dioxide level in the blood is already at a reduced level. The result is an excessive loss of carbon dioxide from the body, which can lead to unconsciousness due to the respiratory system's overriding mechanism to regain control of breathing.

Pilots encountering an unexpected stressful situation may unconsciously increase their breathing rate. If flying at higher altitudes, either with or without oxygen, a pilot may have a tendency to breathe more rapidly than normal, which often leads to hyperventilation.

Since many of the symptoms of hyperventilation are similar to those of hypoxia, it is important to correctly diagnose and treat the proper condition. If using supplemental oxygen, check the equipment and flow rate to ensure the symptoms are not hypoxia related. Common symptoms of hyperventilation include:

- Headache
- Decreased reaction time
- Impaired judgment
- Euphoria
- Visual impairment
- Drowsiness
- Lightheaded or dizzy sensation
- Tingling in fingers and toes
- Numbness
- Pale, clammy appearance
- Muscle spasms

Hyperventilation may produce a pale, clammy appearance and muscle spasms compared to the cyanosis and limp muscles associated with hypoxia. The treatment for hyperventilation involves restoring the proper carbon dioxide level in the body. Breathing normally is both the best prevention and the best cure for hyperventilation. In addition to slowing the breathing rate, breathing into a paper bag or talking aloud helps to overcome hyperventilation. Recovery is usually rapid once the breathing rate is returned to normal.

MIDDLE EAR AND SINUS PROBLEMS

Climbs and descents can sometimes cause ear or sinus pain and a temporary reduction in the ability to hear. The physiological explanation for this discomfort is a difference between the pressure of the air outside the body and that of the air inside the middle ear and nasal sinuses.

The middle ear is a small cavity located in the bone of the skull. It is closed off from the external ear canal by the eardrum. Normally, pressure differences between the middle ear and the outside world are equalized by a tube leading from inside each ear to the back of the throat on each side, called the eustachian tube. These tubes are usually closed, but open during chewing, yawning, or swallowing to equalize pressure. Even a slight difference between external pressure and middle ear pressure can cause discomfort. [Figure 15-2]

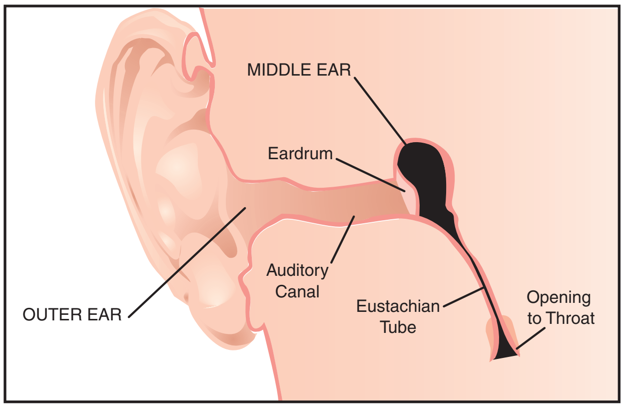


Figure 15-2. The eustachian tube allows air pressure to equalize in the middle ear.

During a climb, middle ear air pressure may exceed the pressure of the air in the external ear canal, causing the eardrum to bulge outward. Pilots become aware of this pressure change when they experience alternate sensations of "fullness" and "clearing." During descent, the reverse happens. While the pressure of the air in the external ear canal increases, the middle ear cavity, which equalized with the lower pressure at altitude, is at lower pressure than the external ear canal. This results in the higher outside pressure, causing the eardrum to bulge inward.

This condition can be more difficult to relieve due to the fact that the partial vacuum tends to constrict the walls of the eustachian tube. To remedy this often painful condition, which also causes a temporary reduction in hearing sensitivity, pinch the nostrils shut, close the mouth and lips, and blow slowly and gently in the mouth and nose.

This procedure forces air through the eustachian tube into the middle ear. It may not be possible to equalize the pressure in the ears if a pilot has a cold, an ear infection, or sore throat. A flight in this condition can be extremely painful, as well as damaging to the eardrums. If experiencing minor congestion, nose drops or nasal sprays may reduce the chance of a painful ear blockage. Before using any medication, check with an aviation medical examiner to ensure that it will not affect the ability to fly.

In a similar way, air pressure in the sinuses equalizes with the pressure in the cockpit through small openings that connect the sinuses to the nasal passages. An upper respiratory infection, such as a cold or sinusitis, or a nasal allergic condition can produce enough congestion around an opening to slow equalization. As the difference in pressure between the sinus and the cockpit increases, congestion may plug the opening. This "sinus block" occurs most frequently during descent. Slow descent rates can reduce the associated pain. A sinus block can occur in the frontal sinuses, located above each eyebrow, or in the maxillary sinuses, located in each upper cheek. It will usually produce excruciating pain over the sinus area. A maxillary sinus block can also make the upper teeth ache. Bloody mucus may discharge from the nasal passages.

Sinus block can be avoided by not flying with an upper respiratory infection or nasal allergic condition. Adequate protection is usually not provided by decongestant sprays or drops to reduce congestion around the sinus openings. Oral decongestants have side effects that can impair pilot performance. If a sinus block does not clear shortly after landing, a physician should be consulted.

SPATIAL DISORIENTATION AND ILLUSIONS

Spatial disorientation specifically refers to the lack of orientation with regard to the position, attitude, or movement of the airplane in space. The body uses three integrated systems working together to ascertain orientation and movement in space. The eye is by far the largest source of information. Kinesthesia refers to the sensation of position, movement, and tension perceived through the nerves, muscles, and tendons. The vestibular system is a very sensitive motion sensing system located in the inner ears. It reports head position, orientation, and movement in three-dimensional space.

All this information comes together in the brain, and most of the time, the three streams of information agree, giving a clear idea of where and how the body is moving. Flying can sometimes cause these systems to supply conflicting information to the brain, which can lead to disorientation. During flight in visual meteorological conditions (VMC), the eyes are the major orientation source and usually prevail over false sensations from other sensory systems. When these visual cues are taken away, as they are in instrument meteorological conditions (IMC), false sensations can cause a pilot to quickly become disoriented.

The vestibular system in the inner ear allows the pilot to sense movement and determine orientation

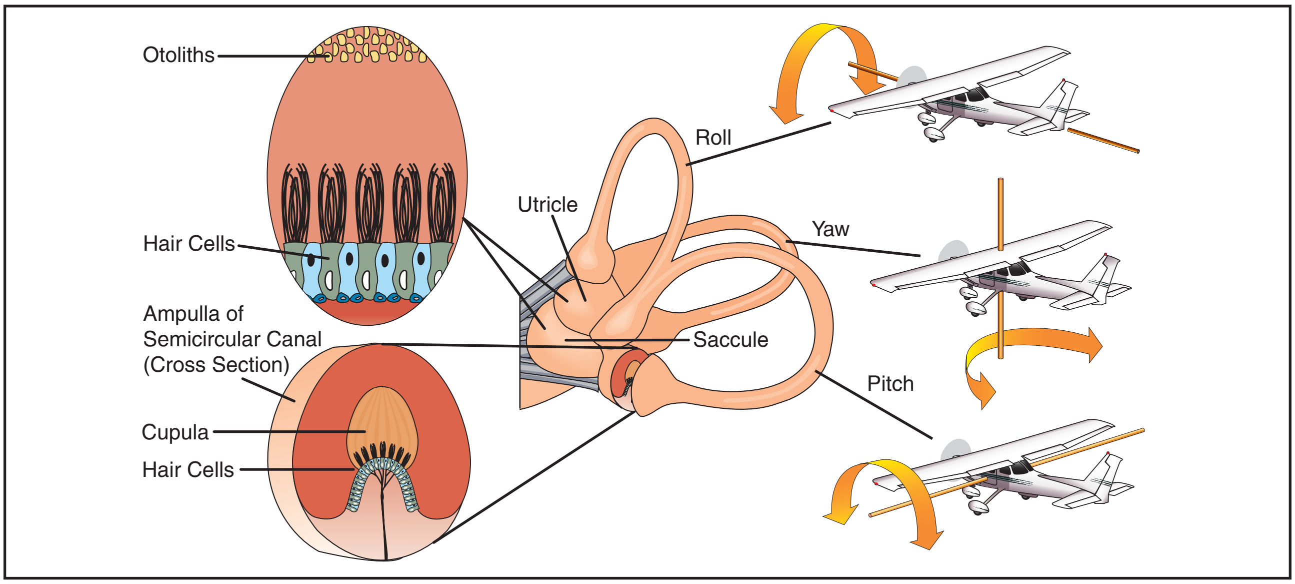


Figure 15-3. The semicircular canals lie in three planes, and sense motions of roll, pitch, and yaw.

in the surrounding environment. In both the left and right inner ear, three semicircular canals are positioned at approximate right angles to each other. Each canal is filled with fluid and has a section full of fine hairs. Acceleration of the inner ear in any direction causes the tiny hairs to deflect, which in turn stimulates nerve impulses, sending messages to the brain. The vestibular nerve transmits the impulses from the utricle, saccule, and semicircular canals to the brain to interpret motion. [Figure 15-3]

The postural system sends signals from the skin, joints, and muscles to the brain that are interpreted in relation to the earth's gravitational pull. These signals determine posture. Inputs from each movement update the body's position to the brain on a constant basis. "Seat of the pants" flying is largely dependent upon these signals. Used in conjunction with visual and vestibular clues, these sensations can be fairly reliable. However, the body cannot distinguish between acceleration forces due to gravity and those resulting from maneuvering the aircraft, which can lead to sensory illusions and false impressions of the airplane's orientation and movement.

Under normal flight conditions, when there is a visual reference to the horizon and ground, the sensory system in the inner ear helps to identify the pitch, roll, and yaw movements of the airplane. When visual contact with the horizon is lost, the vestibular system becomes unreliable. Without visual references outside the airplane, there are many situations where combinations of normal motions and forces can create convincing illusions that are difficult to overcome. In a classic example, a pilot may believe the airplane is in level flight, when, in reality, it is in a gradual turn. If the airspeed increases, the pilot may experience a postural sensation of a level dive and pull back on the stick, which tightens the turn and creates increasing G-loads. If recovery is not initiated, a steep spiral will develop. This is sometimes called the graveyard spiral, because if the pilot fails to recognize that the airplane is in a spiral and fails to return the airplane to wings-level flight, the airplane will eventually strike the ground. If the horizon becomes visible again, the pilot will have an opportunity to return the airplane to straight-and-level flight, and continued visual contact with the horizon will allow the pilot to maintain straight-and-level flight. However, if contact with the horizon is lost again, the inner ear may fool the pilot into thinking the airplane has started a bank in the other direction, causing the graveyard spiral to begin all over again.

Prevention is usually the best remedy for spatial disorientation. Unless a pilot has many hours of training in instrument flight, flight in reduced visibility or at night when the horizon is not visible should be avoided. A pilot can reduce susceptibility to disorienting illusions through training and awareness, and learning to rely totally on flight instruments.

Besides the sensory illusions due to misleading inputs to the vestibular system, a pilot may also encounter various visual illusions during flight. Illusions rank among the most common factors cited as contributing to fatal airplane accidents.

Sloping cloud formations, an obscured horizon, a dark scene spread with ground lights and stars, and certain geometric patterns of ground light can create illusions of not being aligned correctly with the actual horizon. Various surface features and atmospheric conditions encountered in landing can create illusions of being on the wrong approach path. Landing errors from these illusions can be prevented by anticipating them during approaches, inspecting unfamiliar airports before landing, using electronic glide slope or VASI systems when available, and maintaining proficiency in landing procedures.

A narrower-than-usual runway can create the illusion that the airplane is higher than it actually is, while a wider-than-usual runway can have the opposite effect, causing the pilot to flare too high or overshoot the runway. [Figure 15-4]

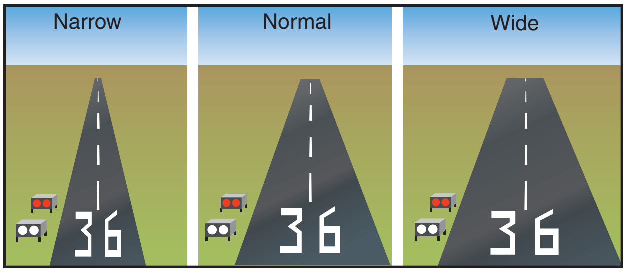


Figure 15-4. Runway Illusions.

A runway that slopes up, or upsloping terrain, can create the illusion that the airplane is at a higher altitude than it actually is, and downsloping runways or terrain can create the opposite effect. Rain on the windshield can create the illusion of greater height, and haze can make distances appear greater than they are.

At sunrise or sunset, a pilot may encounter flicker vertigo. In some individuals, flashing lights at certain frequencies can trigger seizures, nausea, convulsions, or unconsciousness. Seeing the sun through a slow-moving propeller can produce the effect of a flashing light. So can bright light reflecting off the back of the propeller. Symptoms are rare, but be aware of the possibility.

MOTION SICKNESS

Motion sickness, or airsickness, is caused by the brain receiving conflicting messages about the state of the body. A pilot may experience motion sickness during initial flights, but it generally goes away within the first few lessons. Anxiety and stress, which may be experienced at the beginning of flight training, can contribute to motion sickness. Symptoms of motion sickness include general discomfort, nausea, dizziness, paleness, sweating, and vomiting.

It is important to remember that experiencing airsickness is no reflection on one's ability as a pilot. If prone to motion sickness, let the flight instructor know since there are techniques that can be used to overcome this problem. For example, avoid lessons in turbulent conditions until becoming more comfortable in the airplane, or start with shorter flights and graduate to longer instruction periods. If symptoms of motion sickness are experienced during a lesson, opening fresh air vents, focusing on objects outside the airplane, and avoiding unnecessary head movements may help alleviate some of the discomfort. Although medications like Dramamine can prevent airsickness in passengers, they are not recommended while flying since they can cause drowsiness and other problems.

CARBON MONOXIDE POISONING

Carbon monoxide (CO) is a colorless and odorless gas produced by all internal combustion engines. Since it attaches itself to the hemoglobin in the blood about 200 times more easily than oxygen, carbon monoxide prevents the hemoglobin from carrying oxygen to the cells, resulting in hypemic hypoxia. It can take up to 48 hours for the body to dispose of carbon monoxide. If the poisoning is severe enough, it can result in death. Aircraft heater vents and defrost vents may provide carbon monoxide a passageway into the cabin, particularly if the engine exhaust system has a leak or is damaged. If a strong odor of exhaust gases is detected, assume that carbon monoxide is present. However, carbon monoxide may be present in dangerous amounts even if no exhaust odor is detected. Disposable, inexpensive carbon monoxide detectors are widely available. In the presence of carbon monoxide, these detectors change color to alert the pilot of the presence of carbon monoxide. Some effects of carbon monoxide poisoning include headache, blurred vision, dizziness, drowsiness, and/or loss of muscle power. Anytime a pilot smells exhaust odor, or any time that these symptoms are experienced, immediate corrective actions should be taken. These include turning off the heater, opening fresh air vents and windows, and using supplemental oxygen, if available.

Tobacco smoke also causes carbon monoxide poisoning. Smoking at sea level can raise the CO concentration in the blood and result in physiological effects similar to flying at 8,000 feet. Besides hypoxia, tobacco causes diseases and physiological debilitation that are medically disqualifying for pilots.

STRESS

Stress is defined as the body's response to physical and psychological demands placed upon it. The body's reaction to stress includes releasing chemical hormones (such as adrenaline) into the blood, and increasing metabolism to provide more energy to the muscles. The blood sugar, heart rate, respiration, blood pressure, and perspiration all increase. The term "stressor" is used to describe an element that causes an individual to experience stress. Examples of stressors include physical stress (noise or vibration), physiological stress (fatigue), and psychological stress (difficult work or personal situations).

Stress falls into two broad categories, including acute stress (short term) and chronic stress (long term). Acute stress involves an immediate threat that is perceived as danger. This is the type of stress that triggers a "fight or flight" response in an individual, whether the threat is real or imagined. Normally, a healthy person can cope with acute stress and prevent stress overload. However, on-going acute stress can develop into chronic stress.

Chronic stress can be defined as a level of stress that presents an intolerable burden, exceeds the ability of an individual to cope, and causes individual performance to fall sharply. Unrelenting psychological pressures, such as loneliness, financial worries, and relationship or work problems can produce a cumulative level of stress that exceeds a person's ability to cope with the situation. When stress reaches these levels, performance falls off rapidly. Pilots experiencing this level of stress are not safe and should not exercise their airman privileges. Pilots who suspect they are suffering from chronic stress should consult a physician.

FATIGUE

Fatigue is frequently associated with pilot error. Some of the effects of fatigue include degradation of attention and concentration, impaired coordination, and decreased ability to communicate. These factors can seriously influence the ability to make effective decisions. Physical fatigue can result from sleep loss, exercise, or physical work. Factors such as stress and prolonged performance of cognitive work can result in mental fatigue.

Like stress, fatigue also falls into two broad categories: acute and chronic. Acute fatigue is short term and is a normal occurrence in everyday living. It is the kind of tiredness people feel after a period of strenuous effort, excitement, or lack of sleep. Rest after exertion and 8 hours of sound sleep ordinarily cures this condition.

A special type of acute fatigue is skill fatigue. This type of fatigue has two main effects on performance:

- **Timing disruption**—Appearing to perform a task as usual, but the timing of each component is slightly off. This makes the pattern of the operation less smooth, because the pilot performs each component as though it were separate, instead of part of an integrated activity.
- **Disruption of the perceptual field**—Concentrating attention upon movements or objects in the center of vision and neglecting those in the periphery. This may be accompanied by loss of accuracy and smoothness in control movements.

Acute fatigue has many causes, but the following are among the most important for the pilot:

- Mild hypoxia (oxygen deficiency)
- Physical stress
- Psychological stress
- Depletion of physical energy resulting from psychological stress

Sustained psychological stress accelerates the glandular secretions that prepare the body for quick reactions during an emergency. These secretions make the circulatory and respiratory systems work harder, and the liver releases energy to provide the extra fuel needed for brain and muscle work. When this reserve energy supply is depleted, the body lapses into generalized and severe fatigue.

Acute fatigue can be prevented by a proper diet and adequate rest and sleep. A well-balanced diet prevents the body from having to consume its own tissues as an energy source. Adequate rest maintains the body's store of vital energy.

Chronic fatigue, extending over a long period of time, usually has psychological roots, although an underlying disease is sometimes responsible. Continuous high stress levels, for example, can produce chronic fatigue. Chronic fatigue is not relieved by proper diet and adequate rest and sleep, and usually requires treatment by a physician. An individual may experience this condition in the form of weakness, tiredness, palpitations of the heart, breathlessness, headaches, or irritability. Sometimes chronic fatigue even creates stomach or intestinal problems and generalized aches and pains throughout the body. When the condition becomes serious enough, it can lead to emotional illness.

If suffering from acute fatigue, stay on the ground. If fatigue occurs in the cockpit, no amount of training or experience can overcome the detrimental effects. Getting adequate rest is the only way to prevent fatigue from occurring. Avoid flying without a full night's rest, after working excessive hours, or after an especially exhausting or stressful day. Pilots who suspect they are suffering from chronic fatigue should consult a physician.

DEHYDRATION AND HEATSTROKE

Dehydration is the term given to a critical loss of water from the body. The first noticeable effect of dehydration is fatigue, which in turn makes top physical and mental performance difficult, if not impossible. As a pilot, flying for long periods in hot summer temperatures or at high altitudes increases the susceptibility of dehydration since the dry air at altitude tends to increase the rate of water loss from the body. If this fluid is not replaced, fatigue progresses to dizziness, weakness, nausea, tingling of hands and feet, abdominal cramps, and extreme thirst.

Heatstroke is a condition caused by any inability of the body to control its temperature. Onset of this condition may be recognized by the symptoms of dehydration, but also has been known to be recognized only by complete collapse.

To prevent these symptoms, it is recommended that an ample supply of water be carried and used at frequent intervals on any long flight, whether thirsty or not. If the airplane has a canopy or roof window, wearing light-colored, porous clothing and a hat will help provide protection from the sun. Keeping the cockpit well ventilated aids in dissipating excess heat.

ALCOHOL

Alcohol impairs the efficiency of the human mechanism. Studies have positively proven that drinking and performance deterioration are closely linked. Pilots must make hundreds of decisions, some of them time-critical, during the course of a flight. The safe outcome of any flight depends on the ability to make the correct decisions and take the appropriate actions during routine occurrences, as well as abnormal situations. The influence of alcohol drastically reduces the chances of completing a flight without incident. Even in small amounts, alcohol can impair judgment, decrease sense of responsibility, affect coordination, constrict visual field, diminish memory, reduce reasoning power, and lower attention span. As little as one ounce of alcohol can decrease the speed and strength of muscular reflexes, lessen the efficiency of eye movements while reading, and increase the frequency at which errors are committed. Impairments in vision and hearing occur at alcohol blood levels as low as .01 percent.

The alcohol consumed in beer and mixed drinks is ethyl alcohol, a central nervous system depressant. From a medical point of view, it acts on the body much like a general anesthetic. The "dose" is generally much lower and more slowly consumed in the case of alcohol, but the basic effects on the system are similar. Alcohol is easily and quickly absorbed by the digestive tract. The bloodstream absorbs about 80 to 90 percent of the alcohol in a drink within 30 minutes on an empty stomach. The body requires about 3 hours to rid itself of all the alcohol contained in *one* mixed drink or *one* beer.

With a hangover, a pilot is still under the influence of alcohol. Although a pilot may think that he or she is functioning normally, the impairment of motor and mental responses still remains. Considerable amounts of alcohol can remain in the body for over 16 hours, so pilots should be cautious about flying too soon after drinking.

Altitude multiplies the effects of alcohol on the brain. When combined with altitude, the alcohol from two drinks may have the same effect as three or four drinks. Alcohol interferes with the brain's ability to utilize oxygen, producing a form of histotoxic hypoxia. The effects are rapid because alcohol passes so quickly into the bloodstream. In addition, the brain is a highly vascular organ that is immediately sensitive to changes in the blood's composition. For a pilot, the lower oxygen availability at altitude, along with the lower capability of the brain to use what oxygen *is* there, adds up to a deadly combination.

Intoxication is determined by the amount of alcohol in the bloodstream. This is usually measured as a percentage by weight in the blood. 14 CFR part 91 requires that blood alcohol level be less than .04 percent and that 8 hours pass between drinking alcohol and piloting an airplane. A pilot with a blood alcohol level of .04 percent or greater after 8 hours cannot fly until the blood alcohol falls below that amount. Even though blood alcohol may be well below .04 percent, a pilot cannot fly sooner than 8 hours after drinking alcohol. Although the regulations are quite specific, it is a good idea to be more conservative than the regulations.

DRUGS

Pilot performance can be seriously degraded by both prescribed and over-the-counter medications, as well as by the medical conditions for which they are taken. Many medications, such as tranquilizers, sedatives, strong pain relievers, and cough-suppressants have primary effects that may impair judgment, memory, alertness, coordination, vision, and the ability to make calculations. Others, such as antihistamines, blood pressure drugs, muscle relaxants, and agents to control diarrhea and motion sickness have side effects that may impair the same critical functions. Any medication that depresses the nervous system, such as a sedative, tranquilizer, or antihistamine can make a pilot more susceptible to hypoxia.

Pain-killers can be grouped into two broad categories: analgesics and anesthetics. Analgesics are drugs that reduce pain, while anesthetics are drugs that deaden pain or cause loss of consciousness.

Over-the-counter analgesics, such as acetylsalicylic acid (Aspirin), acetaminophen (Tylenol), and ibuprofen (Advil) have few side effects when taken in the correct dosage. Although some people are allergic to certain analgesics or may suffer from stomach irritation, flying usually is not restricted when taking these drugs. However, flying is almost always precluded while using prescription analgesics, such as Darvon, Percodan, Demerol, and codeine since these drugs may cause side effects such as mental confusion, dizziness, headaches, nausea, and vision problems.

Anesthetic drugs are commonly used for dental and surgical procedures. Most local anesthetics used for minor dental and outpatient procedures wear off within a relatively short period of time. The anesthetic itself may not limit flying so much as the actual procedure and subsequent pain.

Stimulants are drugs that excite the central nervous system and produce an increase in alertness and activity. Amphetamines, caffeine, and nicotine are all forms of stimulants. Common uses of these drugs include appetite suppression, fatigue reduction, and mood elevation. Some of these drugs may cause a stimulant reaction, even though this reaction is not their primary function. In some cases, stimulants can produce anxiety and mood swings, both of which are dangerous when flying.

Depressants are drugs that reduce the body's functioning in many areas. These drugs lower blood pressure, reduce mental processing, and slow motor and reaction responses. There are several types of drugs that can cause a depressing effect on the body, including tranquilizers, motion sickness medication, some types of stomach medication, decongestants, and antihistamines. The most common depressant is alcohol.

Some drugs, which can neither be classified as stimulants nor depressants, have adverse effects on flying. For example, some forms of antibiotics can produce dangerous side effects, such as balance disorders, hearing loss, nausea, and vomiting. While many antibiotics are safe for use while flying, the infection requiring the antibiotic may prohibit flying. In addition, unless specifically prescribed by a physician, do not take more than one drug at a time, and never mix drugs with alcohol, because the effects are often unpredictable.

The dangers of illegal drugs also are well documented. Certain illegal drugs can have hallucinatory effects that occur days or weeks after the drug is taken. Obviously, these drugs have no place in the aviation community.

The Code of Federal Regulations prohibits pilots from performing crewmember duties while using any medication that affects the faculties in any way contrary to safety. The safest rule is not to fly as a crewmember while taking any medication, unless approved to do so by the FAA. If there is any doubt regarding the effects of any medication, consult an aviation medical examiner before flying.

SCUBA DIVING

Scuba diving subjects the body to increased pressure, which allows more nitrogen to dissolve in body tissues and fluids. The reduction of atmospheric pressure that accompanies flying can produce physical problems for scuba divers. Reducing the pressure too quickly allows small bubbles of nitrogen to form inside the body as the gas comes out of solution. These bubbles can cause a painful and potentially incapacitating condition called "the bends." (An example is dissolved gas forming bubbles as pressure decreases by slowly opening a transparent bottle of soda.) Scuba training emphasizes how to prevent the bends when rising to the surface, but increased nitrogen concentrations can remain in tissue fluids for several hours after a diver leaves the water. The bends can be experienced from as low as 8,000 feet MSL, with increasing severity as altitude increases. As noted in the *Aeronautical Information Manual* (AIM), the minimum recommended time between scuba diving on nondecompression stop dives and flying is 12 hours, while the minimum time recommended between decompression stop diving and flying is 24 hours. [Figure 15-5]

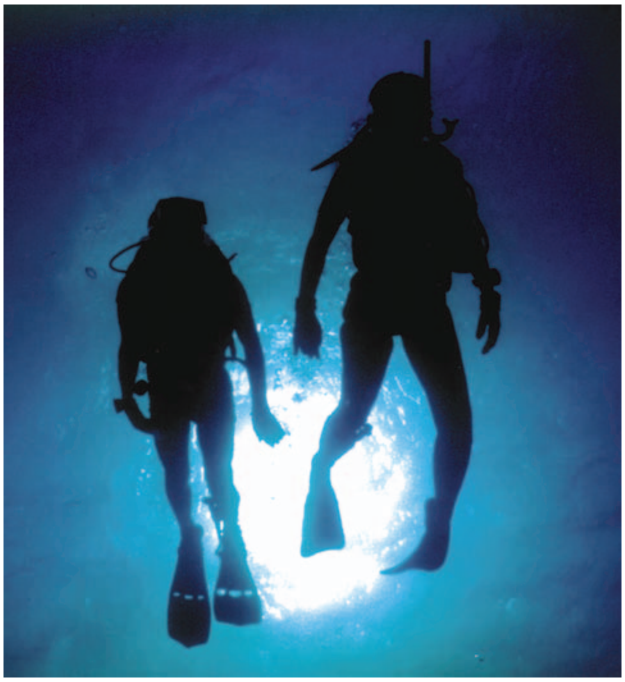


Figure 15-5. Scuba divers must not fly for specific time periods following dives to avoid the bends.

VISION IN FLIGHT

Of all the senses, vision is the most important for safe flight. Most of the things perceived while flying are visual or heavily supplemented by vision. As remarkable and vital as it is, vision is subject to some limitations, such as illusions and blind spots. The more a pilot understands about the eyes and how they function, the easier it is to use vision effectively and compensate for potential problems.

The eye functions much like a camera. Its structure includes an aperture, a lens, a mechanism for focusing, and a surface for registering images. Light enters through the cornea at the front of the eyeball, travels through the lens and falls on the retina. The retina contains light sensitive cells that convert light energy into electrical impulses that travel through nerves to the brain. The brain interprets the electrical signals to form images. There are two kinds of light sensitive cells in the eyes: rods and cones. [Figure 15-6]

The cones are responsible for all color vision, from appreciating a glorious sunset to discerning the subtle shades in a fine painting. Cones are present throughout the retina, but are concentrated toward the center of the field of vision at the back of the retina. There is a small pit called the fovea where almost all the light sensing cells are cones. This is the area where most "looking" occurs (the center of the visual field where detail, color sensitivity, and resolution are highest).

While the cones and their associated nerves are well suited to detecting fine detail and color in high light levels, the rods are better able to detect movement and provide vision in dim light. The rods are unable to discern color but are very sensitive in low light levels. The trouble with rods is that a large amount of light overwhelms them, and they take a long time to "reset" and adapt to the dark again. There are so many cones in the fovea that the very center of the visual field hardly has any rods at all. So in low light, the middle of the visual field isn't very sensitive, but farther from the fovea, the rods are more numerous and provide the major portion of night vision.

The area where the optic nerve enters the eyeball has no rods or cones, leaving a blind spot in the field of vision. Normally, each eye compensates for the other's blind spot. Figure 15-7 provides a dramatic example of the eye's blind spot. Cover the right eye and hold this page at arm's length. Focus the left eye on the X in the right side of the windshield and notice what happens to the airplane while slowly bringing the page closer to the eye.

EMPTY-FIELD MYOPIA

Another problem associated with flying at night, in instrument meteorological conditions and/or reduced visibility is empty-field myopia, or induced nearsightedness. With nothing to focus on, the eyes automatically focus on a point just slightly ahead of the airplane. Searching out and focusing on distant light sources, no matter how dim, helps prevent the onset of empty-field myopia.

NIGHT VISION

It is estimated that once fully adapted to darkness, the rods are 10,000 times more sensitive to light than the cones, making them the primary receptors for night vision. Since the cones are concentrated near the fovea, the rods are also responsible for much of the peripheral vision. The concentration of cones in the fovea can make a night blind spot in the center of the field of vision. To see an object clearly at night, the pilot must expose the rods to the image. This can be done by looking 5° to 10° off center of the object to be seen. This can be tried in a

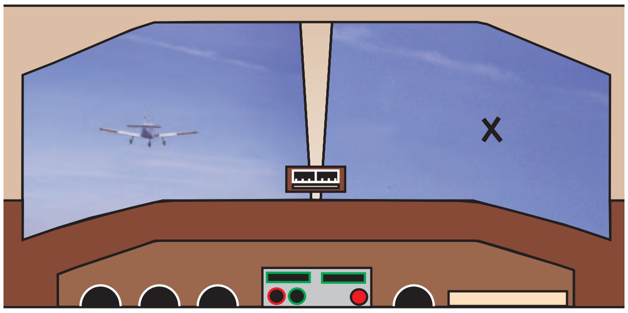


Figure 15-7. The eye's blind spot.

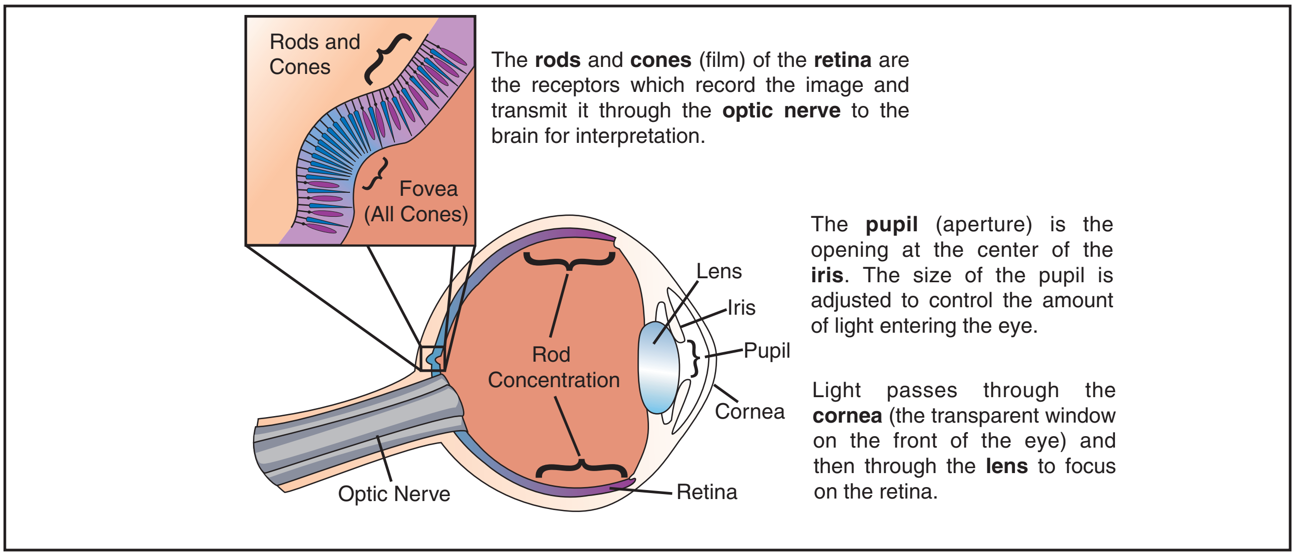


Figure 15-6. The eye.

dim light in a darkened room. When looking directly at the light, it dims or disappears altogether. When looking slightly off center, it becomes clearer and brighter.

Refer to figure 15-8. When looking directly at an object, the image is focused mainly on the fovea, where detail is best seen. At night, the ability to see an object in the center of the visual field is reduced as the cones lose much of their visual acuity and the rods become more sensitive. Looking off center can help compensate for this night blind spot. Along with the loss of sharpness and color at night, depth perception and judgment of size may be lost.

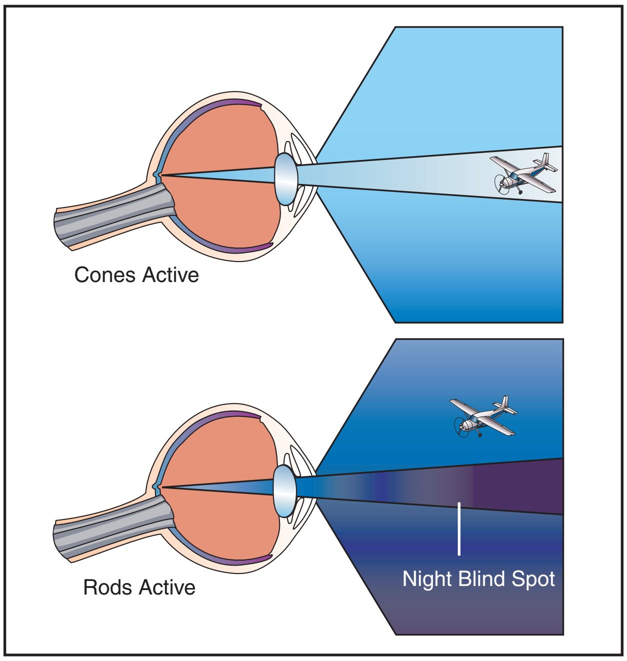


Figure 15-8. Night blind spot.

While the cones adapt rapidly to changes in light intensities, the rods take much longer. Walking from bright sunlight into a dark movie theater is an example of this dark adaptation period experience. The rods can take approximately 30 minutes to fully adapt to the dark. A bright light, however, can completely destroy night adaptation, leaving night vision severely compromised while the adaptation process is repeated.

Several things can be done to keep the eyes adapted to the dark. The first is obvious: avoid bright lights before and during the flight. For 30 minutes before a night flight, avoid any bright light sources, such as headlights, landing lights, strobe lights, or flashlights. If a bright light is encountered, close one eye to keep it light sensitive. This allows the use of that eye to see again once the light is gone.

Red cockpit lighting also helps preserve night vision, but red light severely distorts some colors and completely washes out the color red. This makes reading an aeronautical chart difficult. A dim white light or a carefully directed flashlight can enhance night reading ability. While flying at night, keep the instrument panel and interior lights turned up no higher than necessary. This helps to see outside references more easily. If the eyes become blurry, blinking more frequently often helps.

Diet and general physical health have an impact on how well a pilot can see in the dark. Deficiencies in vitamins A and C have been shown to reduce night acuity. Other factors, such as carbon monoxide poisoning, smoking, alcohol, certain drugs, and a lack of oxygen also can greatly decrease night vision.

NIGHT VISUAL ILLUSIONS

There are many different types of visual illusions that commonly occur at night. Anticipating and staying aware of them is usually the best way to avoid them.

AUTOKINESIS

Autokinesis is caused by staring at a single point of light against a dark background for more than a few seconds. After a few moments, the light appears to move on its own. To prevent this illusion, focus the eyes on objects at varying distances and avoid fixating on one target. Be sure to maintain a normal scan pattern.

FALSE HORIZON

A false horizon can occur when the natural horizon is obscured or not readily apparent. It can be generated by confusing bright stars and city lights. It can also occur while flying toward the shore of an ocean or a large lake. Because of the relative darkness of the water, the lights along the shoreline can be mistaken for stars in the sky. [Figure 15-9]

Figure 15-9. At night, the horizon may be hard to discern due to dark terrain and misleading light patterns on the ground.

NIGHT LANDING ILLUSIONS

Landing illusions occur in many forms. Above featureless terrain at night, there is a natural tendency to fly a lower-than-normal approach. Elements that cause any type of visual obscuration, such as rain, haze, or a dark runway environment also can cause low approaches. Bright lights, steep surrounding terrain, and a wide runway can produce the illusion of being too low, with a tendency to fly a higher-than-normal approach. Often a set of regularly spaced lights along a road or highway can appear to be runway lights. Pilots have even mistaken the lights on moving trains as runway or approach lights. Bright runway or approach lighting systems can create the illusion that the airplane is closer to the runway, especially where few lights illuminate the surrounding terrain.

Chapter 16

Aeronautical Decision Making

Aeronautical decision making (ADM) is a systematic approach to the mental process used by airplane pilots to consistently determine the best course of action in response to a given set of circumstances. The importance of learning effective ADM skills cannot be overemphasized. While progress is continually being made in the advancement of pilot training methods, airplane equipment and systems, and services for pilots, accidents still occur. Despite all the changes in technology to improve flight safety, one factor remains the same—the human factor. It is estimated that approximately 75 percent of all aviation accidents are **human factors** related.

Historically, the term "pilot error" has been used to describe the causes of these accidents. Pilot error means that an action or decision made by the pilot was the cause, or a contributing factor that led to the accident. This definition also includes the pilot's failure to make a decision or take action. From a broader perspective, the phrase "human factors related" more aptly describes these accidents since it is usually not a single decision that leads to an accident, but a chain of events triggered by a number of factors.

The poor judgment chain, sometimes referred to as the "error chain," is a term used to describe this concept of contributing factors in a human factors-related accident. Breaking one link in the chain normally is all that is necessary to change the outcome of the sequence of events. The following is an example illustrating the poor judgment chain.

Human Factors—The study of how people interact with their environments. In the case of general aviation, it is the study of how pilot performance is influenced by such issues as the design of cockpits, the function of the organs of the body, the effects of emotions, and the interaction and communication with the other participants of the aviation community, such as other crewmembers and air traffic control personnel.

A private pilot with around 350 hours was ferrying an airplane cross-country to a new owner. Due to time constraints, the pilot skipped dinner the night before and had no breakfast on the morning of the flight. The pilot planned to have lunch around noon at a fuel stop.

A descent was begun from 9,500 feet, about 20 miles from the chosen fuel stop, due to haze and unfamiliarity with the area. When the airplane arrived at pattern altitude, the pilot could not find the airport. The pilot then circled north of the town, then back over the town, then flew to the west, then turned back to the east.

The pilot decided to check for airport information in the Airport/Facility Directory, which was on the rear seat and not readily available.

Power had not been increased since the descent to pattern altitude, and the pilot had been holding back pressure on the yoke. While attempting to retrieve the Airport/Facility Directory, a loud "bang" was heard. Looking up, the pilot discovered the airplane was only about 200 feet above ground level. Increasing power, the pilot climbed and located the airport. After landing, it was discovered a fiberglass antenna had been hit, which damaged the leading edge of the left wing.

By discussing the events that led to this accident, it can be understood how a series of judgmental errors contributed to the final outcome of this flight. For example, one of the first elements that affected the pilot's flight was fatigue. The pilot understood that fatigue and hunger could affect the ability to fly safely, but let the desire to stay on schedule override the concern for a safe flight.

Next, the rush to get airborne led the pilot to skip or postpone necessary aspects of preflight planning. Research before takeoff, with a quick review before descent, could have ensured a clear mental picture of the location of the airport in relation to the town. Copying relevant information from flight guides and other information sources is part of careful preflight planning. Studying the aeronautical charts and checking the Notices to Airmen (NOTAM) beforehand would have alerted the pilot to towers, terrain, and other obstructions in the vicinity of the airport.

Even without proper planning before the flight, good cockpit resource management and organization would have had the flight guide and any other necessary information near at hand, perhaps with the relevant pages flagged. Approaching the airport environment and flying around the area at traffic pattern altitude in hazy conditions could have interfered with other air traffic, and the potential for a midair collision is obvious.

In all circumstances, the pilot's first duty is to fly the airplane. Clearly that would include adjusting the power, setting the trim, and keeping track of altitude. This pilot was extremely fortunate—the outcome could easily have been fatal.

On numerous occasions during the flight, the pilot could have made effective decisions that would have broken the chain of error and prevented this accident. Making sound decisions is the key to preventing accidents. Traditional pilot training has emphasized flying skills, knowledge of the airplane, and familiarity with regulations. ADM training focuses on the decision-making process and the factors that affect a pilot's ability to make effective choices.

ORIGINS OF ADM TRAINING

The airlines developed some of the first training programs that focused on improving aeronautical decision making. Human factors-related accidents motivated the airline industry to implement crew resource management (CRM) training for flight crews. The focus of CRM programs is the effective use of all available resources; human resources, hardware, and information. Human resources include all groups routinely working with the cockpit crew (or pilot) who are involved in decisions that are required to operate a flight safely. These groups include, but are not limited to: dispatchers, cabin crewmembers, maintenance personnel, and air traffic controllers. Although the CRM concept originated as airlines developed ways of facilitating crew cooperation to improve decision making in the cockpit, CRM principles, such as workload management, situational awareness, communication, the leadership role of the captain, and crewmember coordination have direct application to the general aviation cockpit. This also includes single pilot operations since pilots of small airplanes, as well as crews of larger airplanes, must make effective use of all available resources—human resources, hardware, and information. AC 60-22, *Aeronautical Decision Making*, provides background references, definitions, and other pertinent information about ADM training in the general aviation environment. [Figure 16-1]

THE DECISION-MAKING PROCESS

An understanding of the decision-making process provides a pilot with a foundation for developing ADM skills. Some situations, such as engine failures, require a pilot to respond immediately using established procedures with little time for detailed analysis. Traditionally, pilots have been well trained to react to emergencies, but are not as well prepared to make decisions requiring a more reflective response. Typically during a flight, there is time to examine any changes that occur, gather information, and assess risk before reaching a decision. The steps leading to this conclusion constitute the decision-making process.

DEFINING THE PROBLEM

Problem definition is the first step in the decision-making process. Defining the problem begins with recognizing that a change has occurred or that an expected change did not occur. A problem is perceived first by the senses, then is distinguished through insight and experience. These same abilities, as well as an objective analysis of all available information, are used to determine the exact nature and severity of the problem.

One critical error that can be made during the decision-making process is incorrectly defining the problem. For example, a low oil pressure reading could indicate that the engine is about to fail and an emergency landing should be planned, or it could mean that the oil pressure sensor has failed. The actions to be taken in each of these circumstances would be significantly different. Fixating on a problem that does not exist can divert attention from important tasks. The pilot's failure to maintain an awareness of the circumstances regarding the flight now becomes the problem. This is why once an initial assumption is made regarding the problem, other sources must be used to verify that the conclusion is correct.

DEFINITIONS

AERONAUTICAL DECISION MAKING (ADM) is a systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances.

ATTITUDE is a personal motivational predisposition to respond to persons, situations, or events in a given manner that can, nevertheless, be changed or modified through training as sort of a mental shortcut to decision making.

ATTITUDE MANAGEMENT is the ability to recognize hazardous attitudes in oneself and the willingness to modify them as necessary through the application of an appropriate antidote thought.

CREW RESOURCE MANAGEMENT (CRM) is the application of team management concepts in the flight deck environment. It was initially known as cockpit resource management, but as CRM programs evolved to include cabin crews, maintenance personnel, and others, the phrase crew resource management was adopted. This includes single pilots, as in most general aviation aircraft. Pilots of small aircraft, as well as crews of larger aircraft, must make effective use of all available resources; human resources, hardware, and information. A current definition includes all groups routinely working with the cockpit crew who are involved in decisions required to operate a flight safely. These groups include, but are not limited to: pilots, dispatchers, cabin crewmembers, maintenance personnel, and air traffic controllers. CRM is one way of addressing the challenge of optimizing the human/machine interface and accompanying interpersonal activities.

HEADWORK is required to accomplish a conscious, rational thought process when making decisions. Good decision making involves risk identification and assessment, information processing, and problem solving.

JUDGMENT is the mental process of recognizing and analyzing all pertinent information in a particular situation, a rational evaluation of alternative actions in response to it, and a timely decision on which action to take.

PERSONALITY is the embodiment of personal traits and characteristics of an individual that are set at a very early age and extremely resistant to change.

POOR JUDGMENT CHAIN is a series of mistakes that may lead to an accident or incident. Two basic principles generally associated with the creation of a poor judgment chain are: (1) One bad decision often leads to another; and (2) as a string of bad decisions grows, it reduces the number of subsequent alternatives for continued safe flight. ADM is intended to break the poor judgment chain before it can cause an accident or incident.

RISK ELEMENTS IN ADM take into consideration the four fundamental risk elements: the pilot, the aircraft, the environment, and the type of operation that comprise any given aviation situation.

RISK MANAGEMENT is the part of the decision making process which relies on situational awareness, problem recognition, and good judgment to reduce risks associated with each flight.

SITUATIONAL AWARENESS is the accurate perception and understanding of all the factors and conditions within the four fundamental risk elements that affect safety before, during, and after the flight.

SKILLS and PROCEDURES are the procedural, psychomotor, and perceptual skills used to control a specific aircraft or its systems. They are the airmanship abilities that are gained through conventional training, are perfected, and become almost automatic through experience.

STRESS MANAGEMENT is the personal analysis of the kinds of stress experienced while flying, the application of appropriate stress assessment tools, and other coping mechanisms.

Figure 16-1. These terms are used in AC 60-22 to explain concepts used in ADM training.

While on a cross-country flight, a pilot discovered that fuel consumption was significantly higher than predicted during flight planning. By noticing this discrepancy, change has been recognized. Based on insight, cross-country flying experience, and knowledge of airplane systems, the pilot considers the possibility that there might be enough fuel to reach the destination. Factors that may increase the fuel burn rate could include environmental factors, such as higher-than-expected headwinds and lower-than-expected groundspeed. To determine the severity of the problem, recalculate the fuel consumption and reassess fuel requirements.

CHOOSING A COURSE OF ACTION

After the problem has been identified, the pilot must evaluate the need to react to it and determine the actions that may be taken to resolve the situation in the time available. The expected outcome of each possible action should be considered and the risks assessed before deciding on a response to the situation.

The pilot determines there is insufficient fuel to reach the destination, and considers other options, such as turning around and landing at a nearby airport that has been passed, diverting off course, or landing prior to the destination at an airport on the route. The expected outcome of each possible action must be considered along with an assessment of the risks involved. After studying the aeronautical chart, the pilot concludes that there is an airport that has fueling services within the remaining fuel range along the route. The time expended for the extra fuel stop is a worthwhile investment to ensure a safe completion of the flight.

IMPLEMENTING THE DECISION AND EVALUATING THE OUTCOME

Although a decision may be reached and a course of action implemented, the decision-making process is not complete. It is important to think ahead and determine how the decision could affect other phases of the flight. As the flight progresses, the pilot must continue to evaluate the outcome of the decision to ensure that it is producing the desired result.

To implement the decision, the pilot determines the necessary course changes and calculates a new estimated time of arrival, as well as contacts the nearest flight service station to amend the flight plan and check weather conditions at the fuel stop. Proceeding to the airport, continue to monitor the groundspeed, fuel status, and the weather conditions to ensure that no additional steps need to be taken to guarantee the safety of the flight.

The decision-making process normally consists of several steps before choosing a course of action. To help remember the elements of the decision-making process, a six-step model has been developed using the acronym "DECIDE." [Figure 16-2]

DECIDE MODEL

Detect the fact that a change has occurred.
Estimate the need to counter or react to the change.
Choose a desirable outcome for the success of the flight.
Identify actions which could successfully control the change.
Do the necessary action to adapt to the change.
Evaluate the effect of the action.

Figure 16-2. The DECIDE model can provide a framework for effective decision making.

RISK MANAGEMENT

During each flight, decisions must be made regarding events involving interactions between the four **risk elements**—the pilot in command, the airplane, the environment, and the operation. The decision-making process involves an evaluation of each of these risk elements to achieve an accurate perception of the flight situation. [Figure 16-3]

One of the most important decisions that a pilot in command must make is the go/no-go decision. Evaluating each of these risk elements can help in deciding whether a flight should be conducted or continued. Below is a review of the four risk elements and how they affect decision making regarding the following situations.

Pilot—A pilot must continually make decisions about competency, condition of health, mental and emotional state, level of fatigue, and many other variables. For example, a pilot may be called early in the morning to make a long flight. If a pilot has had only a few hours of sleep and is concerned that the congestion being experienced could be the onset of a cold, it would be prudent to consider if the flight could be accomplished safely.

A pilot had only 4 hours of sleep the night before. The boss then asked the pilot to fly to a meeting in a city 750 miles away. The reported weather was marginal and not expected to improve. After assessing fitness as a pilot, it was decided that it would not be wise to make the flight. The boss was initially unhappy, but later convinced by the pilot that the risks involved were unacceptable.

Airplane—A pilot will frequently base decisions on the evaluations of the airplane, such as performance, equipment, or airworthiness.

Risk Elements—The four components of a flight that make up the overall situation.

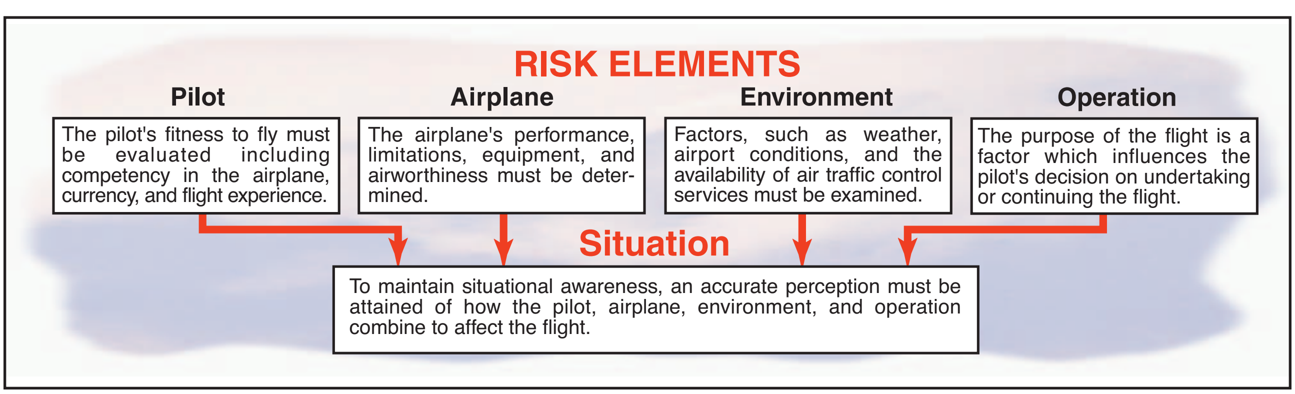


Figure 16-3. When situationally aware, the pilot has an overview of the total operation and is not fixated on one perceived significant factor.

During a preflight, a pilot noticed a small amount of oil dripping from the bottom of the cowling. Although the quantity of oil seemed insignificant at the time, the pilot decided to delay the takeoff and have a mechanic check the source of the oil. The pilot's good judgment was confirmed when the mechanic found that one of the oil cooler hose fittings was loose.

Environment—This encompasses many elements not pilot or airplane related. It can include such factors as weather, air traffic control, navaids, terrain, takeoff and landing areas, and surrounding obstacles. Weather is one element that can change drastically over time and distance.

A pilot was landing a small airplane just after a heavy jet had departed a parallel runway. The pilot assumed that wake turbulence would not be a problem since landings had been performed under similar circumstances. Due to a combination of prevailing winds and wake turbulence from the heavy jet drifting across the landing runway, the airplane made a hard landing. The pilot made an error when assessing the flight environment.

Operation—The interaction between the pilot, airplane, and the environment is greatly influenced by the purpose of each flight operation. The pilot must evaluate the three previous areas to decide on the desirability of undertaking or continuing the flight as planned. It is worth asking why the flight is being made, how critical is it to maintain the schedule, and is the trip worth the risks?

On a ferry flight to deliver an airplane from the factory, in marginal weather conditions, the pilot calculated the groundspeed and determined that the airplane would arrive at the destination with only 10 minutes of fuel remaining. The pilot was determined to keep on schedule by trying to "stretch" the fuel supply instead of landing to refuel. After landing with low fuel state, the pilot realized that this could have easily resulted in an emergency landing in deteriorating weather conditions. This was a chance that was not worth taking to keep the planned schedule.

ASSESSING RISK

Examining National Transportation Safety Board (NTSB) reports and other accident research can help assess risk more effectively. For example, the accident rate during night VFR decreases by nearly 50 percent once a pilot obtains 100 hours, and continues to decrease until the 1,000-hour level. The data suggest that for the first 500 hours, pilots flying VFR at night might want to establish higher personal limitations than are required by the regulations and, if applicable, apply instrument flying skills in this environment. [Figure 16-4]

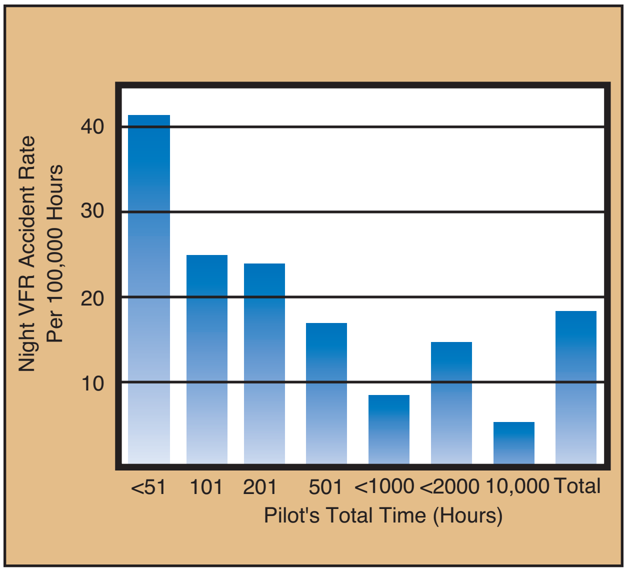


Figure 16-4. Statistical data can identify operations that have more risk involved.

Studies also indicate the types of flight activities that are likely to result in the most serious accidents. The majority of fatal general aviation accidents fall under the categories of takeoff/initial climb, maneuvering flight, approaches, and weather. Delving deeper into accident statistics can provide some important details that can help in understanding the risks involved with specific flying situations. For example, maneuvering flight is one of the largest single producers of fatal accidents. In the approach phase, fatal accidents often happen at night or in IFR conditions. Takeoff/initial climb accidents frequently are due to the pilot's lack of awareness of the effects of density altitude on airplane performance or other improper takeoff planning resulting in loss of control during, or shortly after takeoff. The majority of weather-related accidents occur after attempted VFR flight into IFR conditions.

FACTORS AFFECTING DECISION MAKING

It is important to point out the fact that being familiar with the decision-making process does not ensure the good judgment to be a safe pilot. The ability to make effective decisions as pilot in command depends on a number of factors. Some circumstances, such as the time available to make a decision may be beyond a pilot's control. However, one can learn to recognize those factors that can be managed, and learn skills to improve decision-making ability and judgment.

PILOT SELF-ASSESSMENT

The pilot in command of an airplane is directly responsible for, and is the final authority as to, the operation of that airplane. To effectively exercise that responsibility and make effective decisions regarding the outcome of a flight, a pilot should be aware of personal limitations. Performance during a flight is affected by many factors, such as health, recency of experience, knowledge, skill level, and attitude.

Exercising good judgment begins prior to taking the controls of an airplane. Often, pilots thoroughly check their airplane to determine airworthiness, yet do not evaluate their own fitness for flight. Just as a checklist is used when preflighting an airplane, a personal checklist based on such factors as experience, currency, and comfort level can help determine if a pilot is prepared for a particular flight. Specifying when refresher training should be accomplished and designating weather minimums that may be higher than those listed in Title 14 of the Code of Federal Regulations (14 CFR) part 91 are elements that may be included on a personal checklist. In addition to a review of personal limitations, use the I'M SAFE Checklist to further evaluate fitness for flight. [Figure 16-5]

I'M SAFE CHECKLIST

Illness—Do I have any symptoms?

Medication—Have I been taking prescription or over-the-counter drugs?

Stress—Am I under psychological pressure from the job? Worried about financial matters, health problems, or family discord?

Alcohol—Have I been drinking within 8 hours? Within 24 hours?

Fatigue—Am I tired and not adequately rested?

Eating—Am I adequately nourished?

Figure 16-5. Prior to flight, pilot fitness should be assessed the same as the airplane's airworthiness is evaluated.

RECOGNIZING HAZARDOUS ATTITUDES

Being fit to fly depends on more than just a pilot's physical condition and recency of experience. For example, attitude will affect the quality of decisions. Attitude can be defined as a personal motivational predisposition to respond to persons, situations, or events in a given manner. Studies have identified five hazardous attitudes that can interfere with the ability to make sound decisions and exercise authority properly. [Figure 16-6]

Hazardous attitudes can lead to poor decision making and actions that involve unnecessary risk. The pilot must examine decisions carefully to ensure that the choices have not been influenced by hazardous attitudes and be familiar with positive alternatives to counteract the hazardous attitudes. These substitute attitudes are referred to as antidotes. During a flight operation, it is important to be able to recognize a hazardous attitude, correctly label the thought, and then recall its antidote. [Figure 16-7]

STRESS MANAGEMENT

Everyone is stressed to some degree almost all the time. A certain amount of stress is good since it keeps a person alert and prevents complacency. However, effects of stress are cumulative and, if not coped with adequately, they eventually add up to an intolerable burden. Performance generally increases with the onset of stress, peaks, and then begins to fall off rap-

THE FIVE HAZARDOUS ATTITUDES	
1. Anti-Authority: "Don't tell me."	This attitude is found in people who do not like anyone telling them what to do. In a sense, they are saying, "No one can tell me what to do." They may be resentful of having someone tell them what to do, or may regard rules, regulations, and procedures as silly or unnecessary. However, it is always your prerogative to question authority if you feel it is in error.
2. Impulsivity: "Do it quickly."	This is the attitude of people who frequently feel the need to do something, anything, immediately. They do not stop to think about what they are about to do; they do not select the best alternative, and they do the first thing that comes to mind.
3. Invulnerability: "It won't happen to me."	Many people feel that accidents happen to others, but never to them. They know accidents can happen, and they know that anyone can be affected. They never really feel or believe that they will be personally involved. Pilots who think this way are more likely to take chances and increase risk.
4. Macho: "I can do it."	Pilots who are always trying to prove that they are better than anyone else are thinking, "I can do it –I'll show them." Pilots with this type of attitude will try to prove themselves by taking risks in order to impress others. While this pattern is thought to be a male characteristic, women are equally susceptible.
5. Resignation: "What's the use?"	Pilots who think, "What's the use?" do not see themselves as being able to make a great deal of difference in what happens to them. When things go well, the pilot is apt to think that it is good luck. When things go badly, the pilot may feel that someone is out to get me, or attribute it to bad luck. The pilot will leave the action to others, for better or worse. Sometimes, such pilots will even go along with unreasonable requests just to be a "nice guy."

Figure 16-6. The pilot should examine decisions carefully to ensure that the choices have not been influenced by a hazardous attitude.

HAZARDOUS ATTITUDES	ANTIDOTES
Anti-Authority — Although he knows that flying so low to the ground is prohibited by the regulations, he feels that the regulations are too restrictive in some circumstances.	**Follow the rules. They are usually right.**
Impulsivity — As he is buzzing the park, the airplane does not climb as well as Steve had anticipated and without thinking, Steve pulls back hard on the yoke. The airspeed drops and the airplane is close to a stalling attitude as the wing brushes a power line.	**Not so fast. Think first.**
Invulnerability — Steve is not worried about an accident since he has flown this low many times before and he has not had any problems.	**It could happen to me.**
Macho — Steve often brags to his friends about his skills as a pilot and how close to the ground he flies. During a local pleasure flight in his single-engine airplane, he decides to buzz some friends barbecuing at a nearby park.	**Taking chances is foolish.**
Resignation — Although Steve manages to recover, the wing sustains minor damage. Steve thinks to himself, "It's dangerous for the power company to put those lines so close to a park. If somebody finds out about this I'm going to be in trouble, but it seems like no matter what I do, somebody's always going to criticize."	**I'm not helpless. I can make a difference.**

Figure 16-7. The pilot must be able to identify hazardous attitudes and apply the appropriate antidote when needed.

idly as stress levels exceed a person's ability to cope. The ability to make effective decisions during flight can be impaired by stress. Factors, referred to as stressors, can increase a pilot's risk of error in the cockpit. [Figure 16-8]

There are several techniques to help manage the accumulation of life stresses and prevent stress overload. For example, including relaxation time in a busy schedule and maintaining a program of physical fitness can help reduce stress levels. Learning to manage time more effectively can help avoid heavy pressures imposed by getting behind schedule and not meeting deadlines. Take a self-assessment to determine capabilities and limitations and then set realistic goals. In addition, avoiding stressful situations and encounters can help to cope with stress.

USE OF RESOURCES

To make informed decisions during flight operations, a pilot must become aware of the resources found both inside and outside the cockpit. Since useful tools and sources of information may not always be readily apparent, learning to recognize these resources is an essential part of ADM training. Resources must not only be identified, but a pilot must develop the skills to evaluate whether there is time to use a particular resource and the impact that its use will have upon the safety of flight. For example, the assistance of air traffic control (ATC) may be very useful if a pilot becomes lost. However, in an emergency situation when action needs be taken quickly, time may not be available to contact ATC immediately.

INTERNAL RESOURCES

Internal resources are found in the cockpit during flight. Since some of the most valuable internal resources are ingenuity, knowledge, and skill, a pilot can expand cockpit resources immensely by improving these capabilities. This can be accomplished by frequently reviewing flight information publications, such as the CFRs and the *Aeronautical Information Manual* (AIM), as well as by pursuing additional training.

A thorough understanding of all the equipment and systems in the airplane is necessary to fully utilize all resources. For example, advanced navigation and autopilot systems are valuable resources. However, if pilots do not fully understand how to use this equipment,

STRESSORS
Physical Stress—Conditions associated with the environment, such as temperature and humidity extremes, noise, vibration, and lack of oxygen.
Physiological Stress—Physical conditions, such as fatigue, lack of physical fitness, sleep loss, missed meals (leading to low blood sugar levels), and illness.
Psychological Stress—Social or emotional factors, such as a death in the family, a divorce, a sick child, or a demotion at work. This type of stress may also be related to mental workload, such as analyzing a problem, navigating an aircraft, or making decisions.

Figure 16-8. The three types of stressors that can affect a pilot's performance.

or they rely on it so much that they become complacent, it can become a detriment to safe flight.

Checklists are essential cockpit resources for verifying that the airplane instruments and systems are checked, set, and operating properly, as well as ensuring that the proper procedures are performed if there is a system malfunction or in-flight emergency. In addition, the Airplane Flight Manual/Pilot's Operating Handbook (AFM/POH), which is required to be carried on board the airplane, is essential for accurate flight planning and for resolving in-flight equipment malfunctions. Other valuable cockpit resources include current aeronautical charts and publications, such as the *Airport/Facility Directory*.

Passengers can also be a valuable resource. Passengers can help watch for traffic and may be able to provide information in an irregular situation, especially if they are familiar with flying. A strange smell or sound may alert a passenger to a potential problem. A pilot in command should brief passengers before the flight to make sure that they are comfortable voicing any concerns.

EXTERNAL RESOURCES

Possibly the greatest external resources during flight are air traffic controllers and flight service specialists. ATC can help decrease pilot workload by providing traffic advisories, radar vectors, and assistance in emergency situations. Flight service stations can provide updates on weather, answer questions about airport conditions, and may offer direction-finding assistance. The services provided by ATC can be invaluable in enabling a pilot to make informed in-flight decisions.

WORKLOAD MANAGEMENT

Effective workload management ensures that essential operations are accomplished by planning, prioritizing, and sequencing tasks to avoid work overload. As experience is gained, a pilot learns to recognize future workload requirements and can prepare for high workload periods during times of low workload. Reviewing the appropriate chart and setting radio frequencies well in advance of when they are needed helps reduce workload as the flight nears the airport. In addition, a pilot should listen to ATIS, ASOS, or AWOS, if available, and then monitor the tower frequency or CTAF to get a good idea of what traffic conditions to expect. Checklists should be performed well in advance so there is time to focus on traffic and ATC instructions. These procedures are especially important prior to entering a high-density traffic area, such as Class B airspace.

To manage workload, items should be prioritized. During any situation, and especially in an emergency, remember the phrase "aviate, navigate, and communicate." This means that the first thing the pilot should do is to make sure the airplane is under control. Then begin flying to an acceptable landing area. Only after the first two items are assured should the pilot try to communicate with anyone.

Another important part of managing workload is recognizing a work overload situation. The first effect of high workload is that the pilot begins to work faster. As workload increases, attention cannot be devoted to several tasks at one time, and the pilot may begin to focus on one item. When a pilot becomes task saturated, there is no awareness of inputs from various sources, so decisions may be made on incomplete information, and the possibility of error increases. [Figure 16-9]

When becoming overloaded, stop, think, slow down, and prioritize. It is important to understand options that may be available to decrease workload. For example, tasks such as locating an item on a chart or setting a radio frequency may be delegated to another pilot or passenger; an autopilot, if available, may be used; or ATC may be enlisted to provide assistance.

SITUATIONAL AWARENESS

Situational awareness is the accurate perception of the operational and environmental factors that affect the airplane, pilot, and passengers during a specific period of time. Maintaining situational awareness requires an understanding of the relative significance of these factors and their future impact on the flight. When situationally aware, the pilot has an overview of the total operation and is not fixated on one perceived significant factor. Some of the elements inside the airplane to be considered are the status of airplane systems, and also the pilot and passengers. In addition, an awareness of the environmental conditions of the flight, such as spatial orientation of the airplane, and its relationship to terrain, traffic, weather, and airspace must be maintained.

To maintain situational awareness, all of the skills involved in aeronautical decision making are used. For

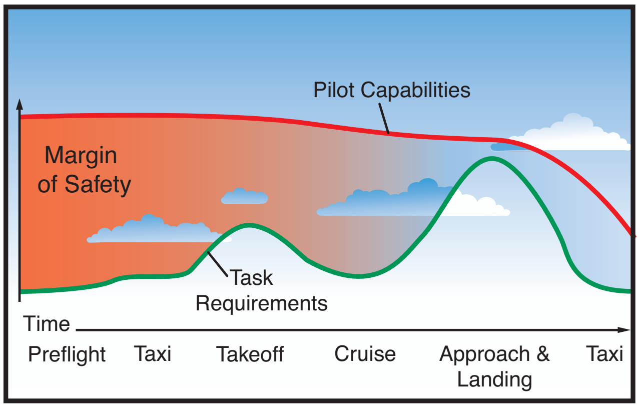


Figure 16-9. Accidents often occur when flying task requirements exceed pilot capabilities. The difference between these two factors is called the margin of safety. Note that in this idealized example, the margin of safety is minimal during the approach and landing. At this point, an emergency or distraction could overtax pilot capabilities, causing an accident.

example, an accurate perception of pilot fitness can be achieved through self-assessment and recognition of hazardous attitudes. A clear assessment of the status of navigation equipment can be obtained through workload management, and establishing a productive relationship with ATC can be accomplished by effective resource use.

OBSTACLES TO MAINTAINING SITUATIONAL AWARENESS

Fatigue, stress, and work overload can cause a pilot to fixate on a single perceived important item rather than maintaining an overall awareness of the flight situation. A contributing factor in many accidents is a distraction that diverts the pilot's attention from monitoring the instruments or scanning outside the airplane. Many cockpit distractions begin as a minor problem, such as a gauge that is not reading correctly, but result in accidents as the pilot diverts attention to the perceived problem and neglects to properly control the airplane.

Complacency presents another obstacle to maintaining situational awareness. When activities become routine, there is a tendency to relax and not put as much effort into performance. Like fatigue, complacency reduces a pilot's effectiveness in the cockpit. However, complacency is harder to recognize than fatigue, since everything is perceived to be progressing smoothly. For example, a pilot has not bothered to calculate the CG of the airplane because it has never been a problem. Without the pilot realizing it, a passenger loads a heavy piece of equipment in the nose baggage compartment. The pilot notices severe nose heaviness during climb-out after takeoff, and finds it necessary to use full nose-up trim to maintain level flight. As the pilot flares for landing, the elevator reaches the stop without raising the nose enough, and the nose-first landing results in loss of the nose gear and extensive damage to the airplane.

OPERATIONAL PITFALLS

There are a number of classic behavioral traps into which pilots have been known to fall. Pilots, particularly those with considerable experience, as a rule, always try to complete a flight as planned, please passengers, and meet schedules. The basic drive to meet or exceed goals can have an adverse effect on safety, and can impose an unrealistic assessment of piloting skills under stressful conditions. These tendencies ultimately may bring about practices that are dangerous and often illegal, and may lead to a mishap. A pilot will develop awareness and learn to avoid many of these operational pitfalls through effective ADM training. [Figure 16-10]

OPERATIONAL PITFALLS

Peer Pressure—Poor decision making may be based upon an emotional response to peers, rather than evaluating a situation objectively.

Mind Set—A pilot displays mind set through an inability to recognize and cope with changes in a given situation.

Get-There-Itis—This disposition impairs pilot judgment through a fixation on the original goal or destination, combined with a disregard for any alternative course of action.

Duck-Under Syndrome—A pilot may be tempted to make it into an airport by descending below minimums during an approach. There may be a belief that there is a built-in margin of error in every approach procedure, or a pilot may want to admit that the landing cannot be completed and a missed approach must be initiated.

Scud Running—This occurs when a pilot tries to maintain visual contact with the terrain at low altitudes while instrument conditions exist.

Continuing Visual Flight Rules (VFR) into Instrument Conditions—Spatial disorientation or collision with ground/obstacles may occur when a pilot continues VFR into instrument conditions. This can be even more dangerous if the pilot is not instrument-rated or current.

Getting Behind the Aircraft—This pitfall can be caused by allowing events or the situation to control pilot actions. A constant state of surprise at what happens next may be exhibited when the pilot is getting behind the aircraft.

Loss of Positional or Situational Awareness—In extreme cases, when a pilot gets behind the aircraft, a loss of positional or situational awareness may result. The pilot may not know the aircraft's geographical location, or may be unable to recognize deteriorating circumstances.

Operating Without Adequate Fuel Reserves—Ignoring minimum fuel reserve requirements is generally the result of overconfidence, lack of flight planning, or disregarding applicable regulations.

Descent Below the Minimum En Route Altitude—The duck-under syndrome, as mentioned above, can also occur during the en route portion of an IFR flight.

Flying Outside the Envelope—The assumed high performance capability of a particular aircraft may cause a mistaken belief that it can meet the demands imposed by a pilot's overestimated flying skills.

Neglect of Flight Planning, Preflight Inspections, and Checklists—A pilot may rely on short- and long-term memory, regular flying skills, and familiar routes instead of established procedures and published checklists. This can be particularly true of experienced pilots.

Figure 16-10. All experienced pilots have fallen prey to, or have been tempted by, one or more of these tendencies in their flying careers.

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100-HOUR INSPECTION — An inspection, identical in scope to an annual inspection. Conducted every 100 hours of flight on aircraft of under 12,500 pounds that are used to carry passengers for hire.

ABSOLUTE ALTITUDE—The vertical distance of an airplane above the terrain, or above ground level (AGL).

ACCELERATION—Force involved in overcoming inertia, and which may be defined as a change in velocity per unit of time.

ACCELERATION ERROR — Fluctuation of the magnetic compass during acceleration. In the Northern Hemisphere, the compass swings toward the north during acceleration.

ACCELERATE-GO DISTANCE — The distance required to accelerate to V_1 with all engines at takeoff power, experience an engine failure at V_1 and continue the takeoff on the remaining engine(s). The runway required includes the distance required to climb to 35 feet by which time V_2 speed must be attained.

ACCELERATE-STOP DISTANCE — The distance required to accelerate to V_1 with all engines at takeoff power, experience an engine failure at V_1, and abort the takeoff and bring the airplane to a stop using braking action only (use of thrust reversing is not considered).

ADF—See AUTOMATIC DIRECTION FINDER.

ADIABATIC COOLING — A process of cooling the air through expansion. For example, as air moves up slope it expands with the reduction of atmospheric pressure and cools as it expands.

ADIABATIC HEATING — A process of heating dry air through compression. For example, as air moves down a slope it is compressed, which results in an increase in temperature.

ADJUSTABLE-PITCH PROPELLER—A propeller with blades whose pitch can be adjusted on the ground with the engine not running, but which cannot be adjusted in flight. Also referred to as a ground adjustable propeller. Sometimes also used to refer to constant-speed propellers that are adjustable in flight.

ADJUSTABLE STABILIZER—A stabilizer that can be adjusted in flight to trim the airplane, thereby allowing the airplane to fly hands-off at any given airspeed.

ADVECTION FOG—Fog resulting from the movement of warm, humid air over a cold surface.

ADVERSE YAW—A condition of flight in which the nose of an airplane tends to yaw toward the outside of the turn. This is caused by the higher induced drag on the outside wing, which is also producing more lift. Induced drag is a by-product of the lift associated with the outside wing.

AERODYNAMICS—The science of the action of air on an object, and with the motion of air on other gases. Aerodynamics deals with the production of lift by the aircraft, the relative wind, and the atmosphere.

AERONAUTICAL CHART — A map used in air navigation containing all or part of the following: topographic features, hazards and obstructions, navigation aids, navigation routes, designated airspace, and airports.

AERONAUTICAL DECISION MAKING (ADM)—A systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances.

AGONIC LINE—Line along which the variation between true and magnetic values is zero.

AILERONS—Primary flight control surfaces mounted on the trailing edge of an airplane wing, near the tip. Ailerons control roll about the longitudinal axis.

AIRCRAFT — A device that is used, or intended to be used, for flight.

AIRCRAFT ALTITUDE—The actual height above sea level at which the aircraft is flying.

AIRFOIL—Any surface, such as a wing, propeller, rudder, or even a trim tab, which provides aerodynamic force when it interacts with a moving stream of air.

AIR MASS—An extensive body of air having fairly uniform properties of temperature and moisture.

AIRMET—In-flight weather advisory concerning moderate icing, moderate turbulence, sustained winds of 30 knots or more at the surface, and widespread areas of ceilings less than 1,000 feet and/or visibility less than 3 miles.

AIRPLANE—An engine-driven, fixed-wing aircraft heavier than air that is supported in flight by the dynamic reaction of air against its wings.

AIRPLANE FLIGHT MANUAL (AFM)—A document developed by the airplane manufacturer and approved by the Federal Aviation Administration (FAA). It is specific to a particular make and model airplane by serial number and it contains operating procedures and limitations.

AIRPLANE OWNER/ INFORMATION MANUAL — A document developed by the airplane manufacturer containing general information about the make and model of an airplane. The airplane owner's manual is not FAA-approved and is not specific to a particular serial numbered airplane. This manual is not kept current, and therefore cannot be substituted for the AFM/POH.

AIRPORT ADVISORY AREA—An area within 10 statute miles (SM) of an airport where a control tower is not operating, but where a flight service station (FSS) is located. At these locations, the FSS provides advisory service to arriving and departing aircraft.

AIRPORT/FACILITY DIRECTORY — A publication designed primarily as a pilot's operational manual containing all airports, seaplane bases, and heliports open to the public including communications data, navigational facilities, and certain special notices and procedures. This publication is issued in seven volumes according to geographical area.

AIRSPEED—Rate of the aircraft's progress through the air.

AIRSPEED INDICATOR — An instrument that is a sensitive, differential pressure gauge which measures and shows promptly the difference between pitot or impact pressure, and static pressure, the undisturbed atmospheric pressure at level flight.

AIRWORTHINESS CERTIFICATE — A certificate issued by the FAA to all aircraft that have been proven to meet the minimum standards set down by the Code of Federal Regulations.

AIRWORTHINESS DIRECTIVE—A regulatory notice sent out by the FAA to the registered owner of an aircraft informing the owner of a condition that prevents the aircraft from continuing to meet its conditions for airworthiness. Airworthiness Directives (AD notes) are to be complied with within the required time limit, and the fact of compliance, the date of compliance, and the method of compliance are recorded in the aircraft's maintenance records.

ALERT AREAS—Areas depicted on aeronautical charts to advise pilots that a high volume of pilot training or unusual aerial activity is taking place.

ALTIMETER—A flight instrument that indicates altitude by sensing pressure changes.

ALTITUDE ENGINE—A reciprocating aircraft engine having a rated takeoff power that is producible from sea level to an established higher altitude.

AMBIENT PRESSURE—The pressure in the area immediately surrounding the aircraft.

AMBIENT TEMPERATURE—The temperature in the area immediately surrounding the aircraft.

ANEROID—A sealed flexible container that expands or contracts in relation to the surrounding air pressure. It is used in an altimeter or a barometer to measure the pressure of the air.

ANGLE OF ATTACK—The acute angle between the chord line of the airfoil and the direction of the relative wind. It is important in the production of lift.

ANGLE OF INCIDENCE—The angle formed by the chord line of the wing and a line parallel to the longitudinal axis of the airplane.

ANHEDRAL—A downward slant from root to tip of an aircraft's wing or horizontal tail surface.

ANNUAL INSPECTION—A complete inspection of an aircraft and engine, required by the Code of Federal Regulations, to be accomplished every 12 calendar months on all certificated aircraft. Only an A&P technician holding an Inspection Authorization can conduct an annual inspection.

ANTISERVO TAB—An adjustable tab attached to the trailing edge of a stabilator that moves in the same direction as the primary control. It is used to make the stabilator less sensitive.

AREA FORECAST (FA)—A report that gives a picture of clouds, general weather conditions, and visual meteorological conditions (VMC) expected over a large area encompassing several states.

AREA NAVIGATION (RNAV)—A system that provides enhanced navigational capability to the pilot. RNAV equipment can compute the airplane position, actual track and groundspeed and then provide meaningful information relative to a route of flight selected by the pilot. Typical equipment will provide the pilot with distance, time, bearing and crosstrack error relative to the selected "TO" or "active" waypoint and the selected route. Several distinctly different navigational systems with different navigational performance characteristics are capable of providing area navigational functions. Present day RNAV includes INS, LORAN, VOR/DME, and GPS systems.

ARM—The horizontal distance in inches from the reference datum line to the center of gravity of an item. The algebraic sign is plus (+) if measured aft of the datum, and minus (-) if measured forward of the datum.

ASPECT RATIO—Span of a wing divided by its average chord.

ASYMMETRIC THRUST—Also known as P-factor. A tendency for an aircraft to yaw to the left due to the descending propeller blade on the right producing more thrust than the ascending blade on the left. This occurs when the aircraft's longitudinal axis is in a climbing attitude in relation to the relative wind. The P-factor would be to the right if the aircraft had a counterclockwise rotating propeller.

ATTITUDE—A personal motivational predisposition to respond to persons, situations, or events in a given manner that can, nevertheless, be changed or modified through training as sort of a mental shortcut to decision making.

ATTITUDE INDICATOR — An instrument that uses an artificial horizon and miniature airplane to depict the position of the airplane in relation to the true horizon. The attitude indicator senses roll as well as pitch, which is the up and down movement of the airplane's nose.

ATTITUDE MANAGEMENT—The ability to recognize hazardous attitudes in oneself and the willingness to modify them as necessary through the application of an appropriate antidote thought.

AUTOKINESIS—This is caused by staring at a single point of light against a dark background for more than a few seconds. After a few moments, the light appears to move on its own.

AUTOMATED SURFACE OBSERVATION SYSTEM (ASOS)—Weather reporting system which provides surface observations every minute via digitized voice broadcasts and printed reports.

AUTOMATED WEATHER OBSERVING SYSTEM (AWOS) — Automated weather reporting system consisting of various sensors, a processor, a computer-generated voice subsystem, and a transmitter to broadcast weather data.

AUTOMATIC DIRECTION FINDER (ADF)—An aircraft radio navigation system which senses and indicates the direction to an L/MF nondirectional radio beacon (NDB) ground transmitter. Direction is indicated to the pilot as a magnetic bearing or as a relative bearing to the longitudinal axis of the aircraft depending on the type of indicator installed in the aircraft. In certain applications, such as military, ADF operations may be based on airborne and ground transmitters in the VHF/UHF frequency spectrum.

AUTOMATIC TERMINAL INFORMATION SERVICE (ATIS)—The continuous broadcast of recorded noncontrol information in selected terminal areas. Its purpose is to improve controller effectiveness and to relieve frequency congestion by automating the repetitive transmission of essential but routine information.

AUTOPILOT—An automatic flight control system which keeps an aircraft in level flight or on a set course. Automatic pilots can be directed by the pilot, or they may be coupled to a radio navigation signal.

AVIATION ROUTINE WEATHER REPORT (METAR)—Observation of current surface weather reported in a standard international format.

AXES OF AN AIRCRAFT—Three imaginary lines that pass through an aircraft's center of gravity. The axes can be considered as imaginary axles around which the aircraft turns. The three axes pass through the center of gravity at 90° angles to each other. The axis from nose to tail is the longitudinal axis, the axis that passes from wingtip to wingtip is the lateral axis and the axis that passes vertically through the center of gravity is the vertical axis.

AXIAL FLOW COMPRESSOR—A type of compressor used in a turbine engine in which the airflow through the compressor is essentially linear. An axial-flow compressor is made up of several stages of alternate rotors and stators. The compressor ratio is determined by the decrease in area of the succeeding stages.

BALANCE TAB—An auxiliary control mounted on a primary control surface, which automatically moves in the direction opposite the primary control to provide an aerodynamic assist in the movement of the control. Sometimes referred to as a servo tab.

BASIC EMPTY WEIGHT (GAMA)—Basic empty weight includes the standard empty weight plus optional and special equipment that has been installed.

BERNOULLI'S PRINCIPLE—A principle that explains how the pressure of a moving fluid varies with its speed of motion. An increase in the speed of movement causes a decrease in the fluid's pressure.

BIPLANES—Airplanes with two sets of wings.

BYPASS RATIO—The ratio of the mass airflow in pounds per second through the fan section of a turbofan engine to the mass airflow that passes through the gas generator portion of the engine.

CABIN ALTITUDE—Cabin pressure in terms of equivalent altitude above sea level.

CALIBRATED AIRSPEED (CAS)—Indicated airspeed corrected for installation error and instrument error. Although manufacturers attempt to keep airspeed errors to a minimum, it is not possible to eliminate all errors throughout the airspeed operating range. At certain airspeeds and with certain flap settings, the installation and instrument errors may total several knots. This error is generally greatest at low airspeeds. In the cruising and higher airspeed ranges, indicated airspeed and calibrated airspeed are approximately the same. Refer to the airspeed calibration chart to correct for possible airspeed errors.

CAMBER—The camber of an airfoil is the characteristic curve of its upper and lower surfaces. The upper camber is more pronounced, while the lower camber is comparatively flat. This causes the velocity of the airflow immediately above the wing to be much higher than that below the wing.

CANARD—A horizontal surface mounted ahead of the main wing to provide longitudinal stability and control. It may be a fixed, movable, or variable geometry surface, with or without control surfaces.

CANARD CONFIGURATION—A configuration in which the span of the forward wings is substantially less than that of the main wing.

CANTILEVER—A wing designed to carry the loads without external struts.

CEILING—The height above the earth's surface of the lowest layer of clouds, which is reported as broken or overcast, or the vertical visibility into an obscuration.

CENTER OF GRAVITY (CG)—The point at which an airplane would balance if it were possible to suspend it at that point. It is the mass center of the airplane, or the theoretical point at which the entire weight of the airplane is assumed to be concentrated. It may be expressed in inches from the reference datum, or in percent of mean aerodynamic chord (MAC). The location depends on the distribution of weight in the airplane.

CENTER-OF-GRAVITY LIMITS—The specified forward and aft points within which the CG must be located during flight. These limits are indicated on pertinent airplane specifications.

CENTER-OF-GRAVITY RANGE—The distance between the forward and aft CG limits indicated on pertinent airplane specifications.

CENTER OF PRESSURE—A point along the wing chord line where lift is considered to be concentrated. For this reason, the center of pressure is commonly referred to as the center of lift.

CENTRIFUGAL FLOW COMPRESSOR—An impeller shaped device that receives air at its center and slings the air outward at high velocity into a diffuser for increased pressure. Also referred to as a radial outflow compressor.

CENTRIFUGAL FORCE — An outward force, that opposes centripetal force, resulting from the effect of inertia during a turn.

CENTRIPETAL FORCE—A center-seeking force directed inward toward the center of rotation created by the horizontal component of lift in turning flight.

CHORD LINE—An imaginary straight line drawn through an airfoil from the leading edge to the trailing edge.

COEFFICIENT OF LIFT—The ratio between lift pressure and dynamic pressure.

COLD FRONT—The boundary between two air masses where cold air is replacing warm air.

COMPLEX AIRCRAFT—An aircraft with retractable landing gear, flaps, and a controllable-pitch propeller.

COMPRESSOR PRESSURE RATIO—The ratio of compressor discharge pressure to compressor inlet pressure.

COMPRESSOR STALL—In gas turbine engines, a condition in an axial-flow compressor in which one or more stages of rotor blades fail to pass air smoothly to the succeeding stages. A stall condition is caused by a pressure ratio that is incompatible with the engine r.p.m. Compressor stall will be indicated by a rise in exhaust temperature or r.p.m. fluctuation, and if allowed to continue, may result in flameout and physical damage to the engine.

CONDENSATION—A change of state of water from a gas (water vapor) to a liquid.

CONDENSATION NUCLEI—Small particles of solid matter in the air on which water vapor condenses.

CONFIGURATION—This is a general term, which normally refers to the position of the landing gear and flaps.

CONSTANT-SPEED PROPELLER—A controllable-pitch propeller whose pitch is automatically varied in flight by a governor to maintain a constant r.p.m. in spite of varying air loads.

CONTINUOUS FLOW OXYGEN SYSTEM—System that supplies a constant supply of pure oxygen to a rebreather bag that dilutes the pure oxygen with exhaled gases and thus supplies a healthy mix of oxygen and ambient air to the mask. Primarily used in passenger cabins of commercial airliners.

CONTROLLABILITY—A measure of the response of an aircraft relative to the pilot's flight control inputs.

CONTROLLED AIRPORT—An airport that has an operating control tower.

CONTROLLED AIRSPACE—A generic term that covers the different classifications of airspace and defined dimensions within which air traffic control service is provided in accordance with the airspace classification. Controlled airspace consists of Class A, B, C, D, and E airspace.

CONVECTIVE SIGMET—A weather advisory concerning convective weather significant to the safety of all aircraft. Convective SIGMETs are issued for tornadoes, lines of thunderstorms, thunderstorms over a wide area, embedded thunderstorms, wind gusts to 50 knots or greater, and/or hail 3/4 inch in diameter or greater.

CONVENTIONAL LANDING GEAR—Landing gear employing a third rear-mounted wheel. These airplanes are also sometimes referred to as tailwheel airplanes.

COUPLED AILERONS AND RUDDER—Rudder and ailerons are connected with interconnect springs in order to counteract adverse yaw. Can be overridden if it becomes necessary to slip the aircraft.

COURSE—The intended direction of flight in the horizontal plane measured in degrees from north.

COWL FLAPS — Shutter-like devices arranged around certain air-cooled engine cowlings, which may be opened or closed to regulate the flow of air around the engine.

CREW RESOURCE MANAGEMENT (CRM)—The application of team management concepts in the flight deck environment. It was initially known as cockpit resource management, but as CRM programs evolved to include cabin crews, maintenance personnel, and others, the phrase "crew resource management" was adopted. This includes single pilots, as in most general aviation aircraft. Pilots of small aircraft, as well as crews of larger aircraft, must make effective use of all available resources; human resources, hardware, and information. A current definition includes all groups routinely working with the cockpit crew who are involved in decisions required to operate a flight safely. These groups include, but are not limited to: pilots, dispatchers, cabin crewmembers, maintenance personnel, and air traffic controllers. CRM is one way of addressing the challenge of optimizing the human/machine interface and accompanying interpersonal activities.

CRITICAL ALTITUDE — The maximum altitude under standard atmospheric conditions at which a turbocharged engine can produce its rated horsepower.

CRITICAL ANGLE OF ATTACK—The angle of attack at which a wing stalls regardless of airspeed, flight attitude, or weight.

DATUM (REFERENCE DATUM)—An imaginary vertical plane or line from which all measurements of arm are taken. The datum is established by the manufacturer. Once the datum has been selected, all moment arms and the location of CG range are measured from this point.

DEAD RECKONING—Navigation of an airplane solely by means of computations based on airspeed, course, heading, wind direction, and speed, groundspeed, and elapsed time.

DECELERATION ERROR—Fluctuation of the magnetic compass during acceleration. In the Northern Hemisphere, the compass swings toward the south during deceleration.

DELTA—A Greek letter expressed by the symbol Δ to indicate a change of values. As an example, ΔCG indicates a change (or movement) of the CG.

DENSITY ALTITUDE—This altitude is pressure altitude corrected for variations from standard temperature. When conditions are standard, pressure altitude and density altitude are the same. If the temperature is above standard, the density altitude is higher than pressure altitude. If the temperature is below standard, the density altitude is lower than pressure altitude. This is an important altitude because it is directly related to the airplane's performance.

DEPOSITION—The direct transformation of a gas to a solid state, in which the liquid state is bypassed. Some sources use sublimation to describe this process instead of deposition.

DETONATION — The sudden release of heat energy from fuel in an aircraft engine caused by the fuel-air mixture reaching its critical pressure and temperature. Detonation occurs as a violent explosion rather than a smooth burning process.

DEVIATION — A compass error caused by magnetic disturbances from electrical and metal components in the airplane. The correction for this error is displayed on a compass correction card placed near the magnetic compass in the airplane.

DEW—Moisture that has condensed from water vapor. Usually found on cooler objects near the ground, such as grass, as the near-surface layer of air cools faster than the layers of air above it.

DEWPOINT—The temperature at which air reaches a state where it can hold no more water.

DIFFERENTIAL AILERONS — Control surface rigged such that the aileron moving up moves a greater distance than the aileron moving down. The up aileron produces extra parasite drag to compensate for the additional induced drag caused by the down aileron. This balancing of the drag forces helps minimize adverse yaw.

DIFFERENTIAL PRESSURE—A difference between two pressures. The measurement of airspeed is an example of the use of differential pressure.

DIHEDRAL—The positive acute angle between the lateral axis of an airplane and a line through the center of a wing or horizontal stabilizer. Dihedral contributes to the lateral stability of an airplane.

DILUTER-DEMAND OXYGEN SYSTEM—An oxygen system that delivers oxygen mixed or diluted with air in order to maintain a constant oxygen partial pressure as the altitude changes.

DIRECT USER ACCESS TERMINAL SERVICE (DUATS)—A computer-based program providing NWS and FAA weather products that are normally used in pilot weather briefings.

DIRECTIONAL STABILITY—Stability about the vertical axis of an aircraft, whereby an aircraft tends to return, on its own, to flight aligned with the relative wind when disturbed from that equilibrium state. The vertical tail is the primary contributor to directional stability, causing an airplane in flight to align with the relative wind.

DISTANCE MEASURING EQUIPMENT (DME)—Equipment (airborne and ground) to measure, in nautical miles, the slant range distance of an aircraft from the DME navigation aid.

DRAG—An aerodynamic force on a body acting parallel and opposite to the relative wind. The resistance of the atmosphere to the relative motion of an aircraft. Drag opposes thrust and limits the speed of the airplane.

DRIFT ANGLE—Angle between heading and track.

DUATS — See DIRECT USER ACCESS TERMINAL SERVICE.

DUTCH ROLL—A combination of rolling and yawing oscillations that normally occurs when the dihedral effects of an aircraft are more powerful than the directional stability. Usually dynamically stable but objectionable in an airplane because of the oscillatory nature.

DYNAMIC HYDROPLANING—A condition that exists when landing on a surface with standing water deeper than the tread depth of the tires. When the brakes are applied, there is a possibility that the brake will lock up and the tire will ride on the surface of the water, much like a water ski. When the tires are hydroplaning, directional control and braking action are virtually impossible. An effective anti-skid system can minimize the effects of hydroplaning.

DYNAMIC STABILITY — The property of an aircraft that causes it, when disturbed from straight-and-level flight, to develop forces or moments that restore the original condition of straight and level.

EDDY CURRENT DAMPING—The decreased amplitude of oscillations by the interaction of magnetic fields. In the case of a vertical card magnetic compass, flux from the oscillating permanent magnet produces eddy currents in a damping disk or cup. The magnetic flux produced by the eddy currents opposes the flux from the permanent magnet and decreases the oscillations.

ELEVATOR—The horizontal, movable primary control surface in the tail section, or empennage, of an airplane. The elevator is hinged to the trailing edge of the fixed horizontal stabilizer.

EMPENNAGE—The section of the airplane that consists of the vertical stabilizer, the horizontal stabilizer, and the associated control surfaces.

EMPTY-FIELD MYOPIA—Induced nearsightedness that is associated with flying at night, in instrument meteorological conditions and/or reduced visibility. With nothing to focus on, the eyes automatically focus on a point just slightly ahead of the airplane.

ENGINE PRESSURE RATIO (EPR)—The ratio of turbine discharge pressure divided by compressor inlet pressure, which is used as an indication of the amount of thrust being developed by a turbine engine.

EN ROUTE FLIGHT ADVISORY SERVICE (EFAS)—A service specifically designed to provide, upon pilot request, timely weather information pertinent to the type of flight, intended route of flight and altitude. The FSSs providing this service are listed in the Airport/Facility Directory. Also known as Flight Watch.

EQUILIBRIUM—A condition that exists within a body when the sum of the moments of all of the forces acting on the body is equal to zero. In aerodynamics, equilibrium is when all opposing forces acting on an aircraft are balanced (steady, unaccelerated flight conditions).

EQUIVALENT AIRSPEED—The airspeed indicator reading corrected for position (or installation), or instrument error, and for adiabatic compressible flow for the particular altitude. (EAS is equal to CAS at sea level in standard atmosphere.)

EVAPORATION—The transformation of a liquid to a gaseous state, such as the change of water to water vapor.

EXHAUST GAS TEMPERATURE (EGT)—The temperature of the exhaust gases as they leave the cylinders of a reciprocating engine or the turbine section of a turbine engine.

EXPLOSIVE DECOMPRESSION—A change in cabin pressure faster than the lungs can decompress. Lung damage is possible.

FIXED-PITCH PROPELLERS—Propellers with fixed blade angles. Fixed-pitch propellers are designed as climb propellers, cruise propellers, or standard propellers.

FIXED SLOT—A fixed, nozzle-shaped opening near the leading edge of a wing that ducts air onto the top surface of the wing. Its purpose is to increase lift at higher angles of attack.

FLAMEOUT—A condition in the operation of a gas turbine engine in which the fire in the engine goes out due to either too much or too little fuel sprayed into the combustors.

FLAPS—Hinged portion of the trailing edge between the ailerons and fuselage. In some aircraft ailerons and flaps are interconnected to produce full-span "flaperons." In either case, flaps change the lift and drag on the wing.

FLOOR LOAD LIMIT—The maximum weight the floor can sustain per square inch/foot as provided by the manufacturer.

FOG—Cloud consisting of numerous minute water droplets and based at the surface; droplets are small enough to be suspended in the earth's atmosphere indefinitely. (Unlike drizzle, it does not fall to the surface; differs from cloud only in that a cloud is not based at the surface; distinguished from haze by its wetness and gray color.)

FORCE (F)—The energy applied to an object that attempts to cause the object to change its direction, speed, or motion. In aerodynamics, it is expressed as F, T (thrust), L (lift), W (weight), or D (drag), usually in pounds.

FOREIGN OBJECT DAMAGE (FOD)—Damage to a gas turbine engine caused by some object being sucked into the engine while it is running. Debris from runways or taxiways can cause foreign object damage during ground operations, and the ingestion of ice and birds can cause FOD in flight.

FRISE-TYPE AILERON—Aileron having the nose portion projecting ahead of the hinge line. When the trailing edge of the aileron moves up, the nose projects below the wing's lower surface and produces some parasite drag, decreasing the amount of adverse yaw.

FRONT—The boundary between two different air masses.

FROST—Ice crystal deposits formed by sublimation when temperature and dewpoint are below freezing.

FUEL LOAD—The expendable part of the load of the airplane. It includes only usable fuel, not fuel required to fill the lines or that which remains trapped in the tank sumps.

FUSELAGE—The section of the airplane that consists of the cabin and/or cockpit, containing seats for the occupants and the controls for the airplane.

GIMBAL RING—A type of support that allows an object, such as a gyroscope, to remain in an upright condition when its base is tilted.

GPS (GLOBAL POSITIONING SYSTEM)—A satellite-based radio positioning, navigation, and time-transfer system.

GROUND ADJUSTABLE TRIM TAB—Non-movable metal trim tab on a control surface. Bent in one direction or another while on the ground to apply trim forces to the control surface.

GROUND EFFECT—The condition of slightly increased air pressure below an airplane wing or helicopter rotor system that increases the amount of lift produced. It exists within approximately one wing span or one rotor diameter from the ground. It results from a reduction in upwash, downwash, and wingtip vortices, and provides a corresponding decrease in induced drag.

GROUNDSPEED (GS)—The actual speed of the airplane over the ground. It is true airspeed adjusted for wind. Groundspeed decreases with a headwind, and increases with a tailwind.

GYROSCOPIC PRECESSION—An inherent quality of rotating bodies, which causes an applied force to be manifested 90º in the direction of rotation from the point where the force is applied.

HAZARDOUS ATTITUDES—These can lead to poor decision making and actions that involve unnecessary risk. Pilots must examine decisions carefully to ensure they have not been influenced by hazardous attitudes.

HAZARDOUS INFLIGHT WEATHER ADVISORY SERVICE (HIWAS) — Continuous recorded hazardous inflight weather forecasts broadcasted to airborne pilots over selected VOR outlets defined as an HIWAS Broadcast Area.

HEADING—The direction in which the nose of the aircraft is pointing during flight.

HEADING INDICATOR — An instrument which senses airplane movement and displays heading based on a 360º azimuth, with the final zero omitted. The heading indicator, also called a directional gyro (DG), is fundamentally a mechanical instrument designed to facilitate the use of the magnetic compass. The heading indicator is not affected by the forces that make the magnetic compass difficult to interpret.

HEADWORK — Required to accomplish a conscious, rational thought process when making decisions. Good decision making involves risk identification and assessment, information processing, and problem solving.

HIGH PERFORMANCE AIRCRAFT—An aircraft with an engine of more than 200 horsepower.

HISTOTOXIC HYPOXIA — The inability of the cells to effectively use oxygen. Plenty of oxygen is being transported to the cells that need it, but they are unable to make use of it.

HORSEPOWER—The term, originated by inventor James Watt, means the amount of work a horse could do in one second. One horsepower equals 550 foot-pounds per second, or 33,000 foot-pounds per minute.

HOT START—In gas turbine engines, a start which occurs with normal engine rotation, but exhaust temperature exceeds prescribed limits. This is usually caused by an excessively rich mixture in the combustor. The fuel to the engine must be terminated immediately to prevent engine damage.

HUMAN FACTORS—The study of how people interact with their environments. In the case of general aviation, it is the study of how pilot performance is influenced by such issues as the design of cockpits, the function of the organs of the body, the effects of emotions, and the interaction and communication with the other participants of the aviation community, such as other crewmembers and air traffic control personnel.

HUNG START— In gas turbine engines, a condition of normal light off but with r.p.m. remaining at some low value rather than increasing to the normal idle r.p.m. This is often the result of insufficient power to the engine from the starter. In the event of a hung start, the engine should be shut down.

HYDROPLANING—A condition that exists when landing on a surface with standing water deeper than the tread depth of the tires. When the brakes are applied, there is a possibility that the brake will lock up and the tire will ride on the surface of the water, much like a water ski. When the tires are hydroplaning, directional control and braking action are virtually impossible. An effective anti-skid system can minimize the effects of hydroplaning.

HYPEMIC HYPOXIA—A type of hypoxia that is a result of oxygen deficiency in the blood, rather than a lack of inhaled oxygen. It can be caused by a variety of factors. Hypemic means "not enough blood."

HYPERVENTILATION—Occurs when an individual is experiencing emotional stress, fright, or pain, and the breathing rate and depth increase, although the carbon dioxide level in the blood is already at a reduced level. The result is an excessive loss of carbon dioxide from the body, which can lead to unconsciousness due to the respiratory system's overriding mechanism to regain control of breathing.

HYPOXIA—Hypoxia means "reduced oxygen" or "not enough oxygen." Hypoxia can be caused by several factors including an insufficient supply of oxygen, inadequate transportation of oxygen, or the inability of the body tissues to use oxygen.

HYPOXIC HYPOXIA—This type of hypoxia is a result of insufficient oxygen available to the lungs. A decrease of oxygen molecules at sufficient pressure can lead to hypoxic hypoxia.

IFR (INSTRUMENT FLIGHT RULES)—Rules that govern the procedure for conducting flight in weather conditions below VFR weather minimums. The term IFR also is used to define weather conditions and the type of flight plan under which an aircraft is operating.

ILS (INSTRUMENT LANDING SYSTEM)—A precision instrument approach system, which normally consists of the following electronic components and visual aids—localizer, glide slope, outer marker, and approach lights.

INCLINOMETER—An instrument consisting of a curved glass tube, housing a glass ball, and damped with a fluid similar to kerosene. It may be used to indicate inclination, as a level, or, as used in the turn indicators, to show the relationship between gravity and centrifugal force in a turn.

INDICATED AIRSPEED (IAS)—The direct instrument reading obtained from the airspeed indicator, uncorrected for variations in atmospheric density, installation error, or instrument error. Manufacturers use this airspeed as the basis for determining airplane performance. Takeoff, landing, and stall speeds listed in the AFM or POH are indicated airspeeds and do not normally vary with altitude or temperature.

INDICATED ALTITUDE — The altitude read directly from the altimeter (uncorrected) when it is set to the current altimeter setting.

INDUCED DRAG—That part of total drag which is created by the production of lift. Induced drag increases with a decrease in airspeed.

INTERCOOLER—A device used to reduce the temperatures of the compressed air before it enters the fuel metering device. The resulting cooler air has a higher density, which permits the engine to be operated with a higher power setting.

INTERPOLATION—The estimation of an intermediate value of a quantity that falls between marked values in a series. Example: In a measurement of length, with a rule that is marked in 1/8's of an inch, the value falls between 3/8 inch and 1/2 inch. The estimated (interpolated) value might then be said to be 7/16 inch.

INVERSION—An increase in temperature with altitude.

ISA (INTERNATIONAL STANDARD ATMOSPHERE)—Standard atmospheric conditions consisting of a temperature of 59°F (15°C), and a barometric pressure of 29.92 in. Hg. (1013.2 mb) at sea level. ISA values can be calculated for various altitudes using a standard lapse rate of approximately 2ºC per 1,000 feet.

ISOBARS—Lines which connect points of equal barometric pressure.

ISOGONIC LINES—Lines on charts that connect points of equal magnetic variation.

JETSTREAM—A narrow band of wind with speeds of 100 to 200 m.p.h. usually co-located with the tropopause.

JUDGMENT—The mental process of recognizing and analyzing all pertinent information in a particular situation, a rational evaluation of alternative actions in response to it, and a timely decision on which action to take.

LAND BREEZE—A coastal breeze flowing from land to sea caused by temperature differences when the sea surface is warmer than the adjacent land. The land breeze usually occurs at night and alternates with the sea breeze that blows in the opposite direction by day.

LATERAL AXIS—An imaginary line passing through the center of gravity of an airplane and extending across the airplane from wingtip to wingtip.

LATERAL STABILITY (ROLLING)—The stability about the longitudinal axis of an aircraft. Rolling stability or the ability of an airplane to return to level flight due to a disturbance that causes one of the wings to drop.

LATITUDE—Measurement north or south of the equator in degrees, minutes, and seconds. Lines of latitude are also referred to as parallels.

LEADING EDGE—The part of an airfoil that meets the airflow first.

LEADING EDGE DEVICES — High lift devices which are found on the leading edge of the airfoil. The most common types are fixed slots, movable slats, and leading edge flaps.

LEADING EDGE FLAP—A portion of the leading edge of an airplane wing that folds downward to increase the camber, lift, and drag of the wing. The leading-edge flaps are extended for takeoffs and landings to increase the amount of aerodynamic lift that is produced at any given airspeed.

LICENSED EMPTY WEIGHT—The empty weight that consists of the airframe, engine(s), unusable fuel, and undrainable oil plus standard and optional equipment as specified in the equipment list. Some manufacturers used this term prior to GAMA standardization.

LIFT—One of the four main forces acting on an aircraft. On a fixed-wing aircraft, an upward force created by the effect of airflow as it passes over and under the wing.

LIMIT LOAD FACTOR—Amount of stress, or load factor, that an aircraft can withstand before structural damage or failure occurs.

LOAD FACTOR—The ratio of the load supported by the airplane's wings to the actual weight of the aircraft and its contents. Also referred to as G-loading.

LONGITUDE—Measurement east or west of the Prime Meridian in degrees, minutes, and seconds. The Prime Meridian is 0° longitude and runs through Greenwich, England. Lines of longitude are also referred to as meridians.

LONGITUDINAL AXIS—An imaginary line through an aircraft from nose to tail, passing through its center of gravity. The longitudinal axis is also called the roll axis of the aircraft. Movement of the ailerons rotates an airplane about its longitudinal axis.

LONGITUDINAL STABILITY (PITCHING)—Stability about the lateral axis. A desirable characteristic of an airplane whereby it tends to return to its trimmed angle of attack after displacement.

LORAN-C—A radio navigation system that utilizes master and slave stations transmitting timed pulses. The time difference in reception of pulses from several stations establishes a hyperbolic line of position, which can be identified on a LORAN chart. A fix in position is obtained by utilizing signals from two or more stations.

MAGNETIC BEARING—The magnetic course to go direct to an NDB station.

MAGNETIC COMPASS—A device for determining direction measured from magnetic north.

MAGNETIC DIP—A vertical attraction between a compass needle and the magnetic poles. The closer the aircraft is to the pole, the more severe the effect. In the Northern Hemisphere, a weight is placed on the south-facing end of the compass needle; in the Southern Hemisphere, a weight is placed on the north-facing end of the compass needle to somewhat compensate for this effect.

MAGNETO—A self-contained, engine-driven unit that supplies electrical current to the spark plugs; completely independent of the airplane's electrical system. Normally there are two magnetos per engine.

MAGNUS EFFECT—Lifting force produced when a rotating cylinder produces a pressure differential. This is the same effect that makes a baseball curve or a golf ball slice.

MANEUVERABILITY—Ability of an aircraft to change directions along a flightpath and withstand the stresses imposed upon it.

MANEUVERING SPEED (V_A) —The maximum speed where full, abrupt control movement can be used without overstressing the airframe.

MANIFOLD ABSOLUTE PRESSURE (MAP)—The absolute pressure of the fuel/air mixture within the intake manifold, usually indicated in inches of mercury.

MASS—The amount of matter in a body.

MAXIMUM LANDING WEIGHT—The greatest weight that an airplane normally is allowed to have at landing.

MAXIMUM RAMP WEIGHT—The total weight of a loaded aircraft, including all fuel. It is greater than the takeoff weight due to the fuel that will be burned during the taxi and runup operations. Ramp weight may also be referred to as taxi weight.

MAXIMUM TAKEOFF WEIGHT—The maximum allowable weight for takeoff.

MAXIMUM WEIGHT—The maximum authorized weight of the aircraft and all of its equipment as specified in the Type Certificate Data Sheets (TCDS) for the aircraft.

MAXIMUM ZERO FUEL WEIGHT (GAMA)—The maximum weight, exclusive of usable fuel.

MEAN AERODYNAMIC CHORD (MAC)—The average distance from the leading edge to the trailing edge of the wing.

MERIDIANS—Lines of longitude.

MESOSPHERE—A layer of the atmosphere directly above the stratosphere.

METAR—See AVIATION ROUTINE WEATHER REPORT.

MICROBURST—A strong downdraft which normally occurs over horizontal distances of 1 NM or less and vertical distances of less than 1,000 feet. In spite of its small horizontal scale, an intense microburst could induce windspeeds greater than 100 knots and downdrafts as strong as 6,000 feet per minute.

MILITARY OPERATION AREAS (MOA)—Airspace that consists of defined vertical and lateral limits established for the purpose of separating certain military training activity from IFR traffic. These are depicted on aeronautical charts.

MILITARY TRAINING ROUTES (MTR)—Routes developed to allow the military to conduct low-altitude, high-speed training. These routes are identified on sectional charts.

MINIMUM DRAG—The point on the total drag curve where the lift-to-drag ratio is the greatest. At this speed, total drag is minimized.

MINIMUM EQUIPMENT LIST (MEL)—A list developed for larger aircraft that outlines equipment that can be inoperative for various types of flight including IFR and icing conditions. This list is based on the master minimum equipment list (MMEL) developed by the FAA and must be approved by the FAA for use. It is specific to an individual aircraft make and model.

MOMENT—The product of the weight of an item multiplied by its arm. Moments are expressed in pound-inches (lb-in). Total moment is the weight of the airplane multiplied by the distance between the datum and the CG.

MOMENT ARM—The distance from a datum to the applied force.

MOMENT INDEX (OR INDEX)—A moment divided by a constant such as 100, 1,000, or 10,000. The purpose of using a moment index is to simplify weight and balance computations of airplanes where heavy items and long arms result in large, unmanageable numbers.

MONOCOQUE—A shell-like fuselage design in which the stressed outer skin is used to support the majority of imposed stresses. Monocoque fuselage design may include bulkheads but not stringers.

MONOPLANES—Airplanes with a single set of wings.

MOVABLE SLAT—A movable auxiliary airfoil on the leading edge of a wing. It is closed in normal flight but extends at high angles of attack. This allows air to continue flowing over the top of the wing and delays airflow separation.

N_1—Rotational speed of the low pressure compressor in a turbine engine.

N_2—Rotational speed of the high pressure compressor in a turbine engine.

NACELLE—A streamlined enclosure on an aircraft in which an engine is mounted. On multiengine propeller-driven airplanes, the nacelle is normally mounted on the leading edge of the wing.

NATIONAL SECURITY AREAS—Airspace that consists of defined vertical and lateral dimensions established at locations where there is a requirement for increased security and safety of ground facilities.

NDB—See NONDIRECTIONAL RADIO BEACON.

NEGATIVE STATIC STABILITY—The initial tendency of an aircraft to continue away from the original state of equilibrium after being disturbed.

NEUTRAL STATIC STABILITY—The initial tendency of an aircraft to remain in a new condition after its equilibrium has been disturbed.

NONDIRECTIONAL RADIO BEACON (NDB)—An L/MF or UHF radio beacon transmitting nondirectional signals whereby the pilot of an aircraft equipped with direction finding equipment can determine the bearing to or from the radio beacon and "home" on or track to or from the station. When the radio beacon is installed in conjunction with the Instrument Landing System marker, it is normally called a Compass Locator.

NOTICES TO AIRMEN (NOTAM)—A notice containing time-critical information that is either of a temporary nature or is not known far enough in advance to permit publication on aeronautical charts or other operation publications. This can include the establishment, condition, or change in any facility, service, procedure, or hazard in the National Airspace System.

OBSTRUCTION LIGHTS—Lights that can be found both on and off an airport to identify obstructions.

OCCLUDED FRONT—A frontal occlusion occurs when a fast-moving cold front catches up with a slow-moving warm front. The difference in temperature within each frontal system is a major factor in determining whether a cold or warm front occlusion occurs.

OUTSIDE AIR TEMPERATURE (OAT)—The measured or indicated air temperature (IAT) corrected for compression and friction heating. Also referred to as true air temperature.

OVERBOOST—A condition in which a reciprocating engine has exceeded the maximum manifold pressure allowed by the manufacturer. Can cause damage to engine components.

PARALLELS—Lines of latitude.

PARASITE DRAG—That part of total drag created by the form or shape of airplane parts. Parasite drag increases with an increase in airspeed.

PAYLOAD (GAMA)—The weight of occupants, cargo, and baggage.

PERSONALITY—The embodiment of personal traits and characteristics of an individual that are set at a very early age and extremely resistant to change.

P-FACTOR—A tendency for an aircraft to yaw to the left due to the descending propeller blade on the right producing more thrust than the ascending blade on the left. This occurs when the aircraft's longitudinal axis is in a climbing attitude in relation to the relative wind. The P-factor would be to the right if the aircraft had a counterclockwise rotating propeller.

PHUGOID OSCILLATIONS —Long-period oscillations of an aircraft around its lateral axis. It is a slow change in pitch accompanied by equally slow changes in airspeed. Angle of attack remains constant, and the pilot often corrects for phugoid oscillations without even being aware of them.

PILOTAGE—Navigation by visual reference to landmarks.

PILOT'S OPERATING HANDBOOK (POH)—A document developed by the airplane manufacturer and contains the FAA-approved Airplane Flight Manual (AFM) information.

PILOT WEATHER REPORT (PIREP)—A report, generated by pilots, concerning meteorological phenomena encountered in flight.

PLANFORM—The shape or form of a wing as viewed from above. It may be long and tapered, short and rectangular, or various other shapes.

PNEUMATIC—Operation by the use of compressed air.

POOR JUDGMENT CHAIN—A series of mistakes that may lead to an accident or incident. Two basic principles generally associated with the creation of a poor judgment chain are: (1) One bad decision often leads to another; and (2) as a string of bad decisions grows, it reduces the number of subsequent alternatives for continued safe flight. ADM is intended to break the poor judgment chain before it can cause an accident or incident.

POSITIVE STATIC STABILITY—The initial tendency to return to a state of equilibrium when disturbed from that state.

POWER—Implies work rate or units of work per unit of time, and as such, it is a function of the speed at which the force is developed. The term, power required, is generally associated with reciprocating engines.

POWERPLANT—A complete engine and propeller combination with accessories.

PRECESSION—The tilting or turning of a gyro in response to deflective forces causing slow drifting and erroneous indications in gyroscopic instruments.

PRECIPITATION—Any or all forms of water particles (rain, sleet, hail, or snow), that fall from the atmosphere and reach the surface.

PREIGNITION—Ignition occurring in the cylinder before the time of normal ignition. Preignition is often caused by a local hot spot in the combustion chamber igniting the fuel-air mixture.

PRESSURE ALTITUDE—The altitude indicated when the altimeter setting window (barometric scale) is adjusted to 29.92. This is the altitude above the standard datum plane, which is a theoretical plane where air pressure (corrected to 15°C) equals 29.92 in. Hg. Pressure altitude is used to compute density altitude, true altitude, true airspeed, and other performance data.

PRESSURE DEMAND OXYGEN SYSTEM—A demand oxygen system that supplies 100 percent oxygen at sufficient pressure above the altitude where normal breathing is adequate. Also referred to as a pressure breathing system.

PREVENTIVE MAINTENANCE—Simple or minor preservative operations and the replacement of small standard parts not involving complex assembly operation as listed in Appendix A of 14 CFR part 43. Certificated pilots may perform preventive maintenance on any aircraft that is owned or operated by them provided that the aircraft is not used in air carrier service.

PROHIBITED AREAS—Areas that are established for security or other reasons associated with the national welfare.

PROPELLER—A device for propelling an aircraft that, when rotated, produces by its action on the air, a thrust approximately perpendicular to its plane of rotation. It includes the control components normally supplied by its manufacturer.

RADAR SERVICES—Radar is a method whereby radio waves are transmitted into the air and are then received when they have been reflected by an object in the path of the beam. Range is determined by measuring the time it takes (at the speed of light) for the radio wave to go out to the object and then return to the receiving antenna. The direction of a detected object from a radar site is determined by the position of the rotating antenna when the reflected portion of the radio wave is received.

RADAR SUMMARY CHART—A weather product derived from the national radar network that graphically displays a summary of radar weather reports.

RADAR WEATHER REPORT (SD)—A report issued by radar stations at 35 minutes after the hour, and special reports as needed. Provides information on the type, intensity, and location of the echo tops of the precipitation.

RADIOSONDE—A weather instrument that observes and reports meteorological conditions from the upper atmosphere. This instrument is typically carried into the atmosphere by some form of weather balloon.

RAM RECOVERY—The increase in thrust as a result of ram air pressures and density on the front of the engine caused by air velocity.

RAPID DECOMPRESSION—The almost instantaneous loss of cabin pressure in aircraft with a pressurized cockpit or cabin.

REGION OF REVERSE COMMAND—Flight regime in which flight at a higher airspeed requires a lower power setting and a lower airspeed requires a higher power setting in order to maintain altitude.

RELATIVE BEARING—An angular relationship between two objects measured in degrees clockwise from the twelve o'clock position of the first object.

RELATIVE HUMIDITY — The ratio of the existing amount of water vapor in the air at a given temperature to the maximum amount that could exist at that temperature; usually expressed in percent.

RELATIVE WIND—The direction of the airflow with respect to the wing. If a wing moves forward horizontally, the relative wind moves backward horizontally. Relative wind is parallel to and opposite the flightpath of the airplane.

RESTRICTED AREAS—Areas that denote the existence of unusual, often invisible hazards to aircraft such as artillery firing, aerial gunnery, or guided missiles. An aircraft may not enter a restricted area unless permission has been obtained from the controlling agency.

RIGGING—The final adjustment and alignment of an aircraft and its flight control system that provides the proper aerodynamic characteristics.

RIGIDITY IN SPACE—The principle that a wheel with a heavily weighted rim spun rapidly will remain in a fixed position in the plane in which it is spinning.

RISK ELEMENTS—There are four fundamental risk elements: the pilot, the aircraft, the environment, and the type of operation that comprise any given aviation situation.

RISK MANAGEMENT—The part of the decision making process which relies on situational awareness, problem recognition, and good judgment to reduce risks associated with each flight.

RNAV—See AREA NAVIGATION.

RUDDER—The movable primary control surface mounted on the trailing edge of the vertical fin of an airplane. Movement of the rudder rotates the airplane about its vertical axis.

RUDDERVATOR—A pair of control surfaces on the tail of an aircraft arranged in the form of a V. These surfaces, when moved together by the control wheel, serve as elevators, and when moved differentially by the rudder pedals, serve as a rudder.

RUNWAY CENTERLINE LIGHTS—Runway lighting which consists of flush centerline lights spaced at 50-foot intervals beginning 75 feet from the landing threshold.

RUNWAY EDGE LIGHTS—A component of the runway lighting system that is used to outline the edges of runways at night or during low visibility conditions. These lights are classified according to the intensity they are capable of producing.

RUNWAY END IDENTIFIER LIGHTS (REIL)—One component of the runway lighting system. These lights are installed at many airfields to provide rapid and positive identification of the approach end of a particular runway.

SEA BREEZE—A coastal breeze blowing from sea to land caused by the temperature difference when the land surface is warmer than the sea surface. The sea breeze usually occurs during the day and alternates with the land breeze that blows in the opposite direction at night.

SEA-LEVEL ENGINE—A reciprocating aircraft engine having a rated takeoff power that is producible only at sea level.

SECTIONAL AERONAUTICAL CHARTS (1:500,000)—Designed for visual navigation of slow or medium speed aircraft. Topographic information on these charts features the portrayal of relief, and a judicious selection of visual check points for VFR flight. Aeronautical information includes visual and radio aids to navigation, airports, controlled airspace, restricted areas, obstructions and related data.

SEMI-MONOCOQUE—A fuselage design that includes a substructure of bulkheads and/or formers, along with stringers, to support flight loads and stresses imposed on the fuselage.

SERVICE CEILING—The maximum density altitude where the best rate-of-climb airspeed will produce a 100 feet-per-minute climb at maximum weight while in a clean configuration with maximum continuous power.

SERVO—A motor or other form of actuator which receives a small signal from the control device and exerts a large force to accomplish the desired work.

SERVO TAB—An auxiliary control mounted on a primary control surface, which automatically moves in the direction opposite the primary control to provide an aerodynamic assist in the movement of the control.

SIGMET—An in-flight weather advisory that is considered significant to all aircraft. SIGMET criteria include severe icing, severe and extreme turbulence, duststorms, sandstorms, volcanic eruptions, and volcanic ash that lower visibility to less than 3 miles.

SIGNIFICANT WEATHER PROGNOSTIC CHART—Presents four panels showing forecast significant weather and forecast surface weather.

SITUATIONAL AWARENESS—The accurate perception and understanding of all the factors and conditions within the four fundamental risk elements that affect safety before, during, and after the flight.

SKILLS AND PROCEDURES—The procedural, psychomotor, and perceptual skills used to control a specific aircraft or its systems. They are the airmanship abilities that are gained through conventional training, are perfected, and become almost automatic through experience.

SPATIAL DISORIENTATION—Specifically refers to the lack of orientation with regard to the position, attitude, or movement of the airplane in space.

SPECIAL FLIGHT PERMIT—A flight permit issued to an aircraft that does not meet airworthiness requirements but is capable of safe flight. A special flight permit can be issued to move an aircraft for the purposes of maintenance or repair, buyer delivery, manufacturer flight tests, evacuation from danger, or customer demonstration. Also referred to as a ferry permit.

SPECIAL USE AIRSPACE—Airspace that exists where activities must be confined because of their nature.

SPECIFIC FUEL CONSUMPTION—The amount of fuel in pounds per hour consumed or required by an engine per brake horsepower or per pound of thrust.

SPEED—The distance traveled in a given time.

SPIN—An aggravated stall that results in an airplane descending in a helical, or corkscrew path.

SPIRAL INSTABILITY—A condition that exists when the static directional stability of the airplane is very strong as compared to the effect of its dihedral in maintaining lateral equilibrium.

SPIRALING SLIPSTREAM—The slipstream of a propeller-driven airplane rotates around the airplane. This slipstream strikes the left side of the vertical fin, causing the aircraft to yaw slightly. Rudder offset is sometimes used by aircraft designers to counteract this tendency.

SPOILERS—High-drag devices that can be raised into the air flowing over an airfoil, reducing lift and increasing drag. Spoilers are used for roll control on some aircraft. Deploying spoilers on both wings at the same time allows the aircraft to descend without gaining speed. Spoilers are also used to shorten the ground roll after landing.

STABILATOR—A single-piece horizontal tail surface on an airplane that pivots around a central hinge point. A stabilator serves the purposes of both the horizontal stabilizer and the elevators.

STABILITY—The inherent quality of an airplane to correct for conditions that may disturb its equilibrium, and to return or to continue on the original flightpath. It is primarily an airplane design characteristic.

STAGNANT HYPOXIA—A type of hypoxia that results when the oxygen-rich blood in the lungs isn't moving, for one reason or another, to the tissues that need it.

STALL—A rapid decrease in lift caused by the separation of airflow from the wing's surface brought on by exceeding the critical angle of attack. A stall can occur at any pitch attitude or airspeed.

STANDARD ATMOSPHERE—At sea level, the standard atmosphere consists of a barometric pressure of 29.92 inches of mercury (in. Hg.) or 1013.2 millibars, and a temperature of 15°C (59°F). Pressure and temperature normally decrease as altitude increases. The standard lapse rate in the lower atmosphere for each 1,000 feet of altitude is approximately 1 in. Hg. and 2°C (3.5°F). For example, the standard pressure and temperature at 3,000 feet mean sea level (MSL) is 26.92 in. Hg. (29.92 - 3) and 9°C (15°C - 6°C).

STANDARD EMPTY WEIGHT (GAMA)—This weight consists of the airframe, engines, and all items of operating equipment that have fixed locations and are permanently installed in the airplane; including fixed ballast, hydraulic fluid, unusable fuel, and full engine oil.

STANDARD-RATE-TURN—A turn at the rate of 3º per second which enables the airplane to complete a 360º turn in 2 minutes.

STANDARD WEIGHTS—These have been established for numerous items involved in weight and balance computations. These weights should not be used if actual weights are available.

STATIC STABILITY—The initial tendency an aircraft displays when disturbed from a state of equilibrium.

STATION—A location in the airplane that is identified by a number designating its distance in inches from the datum. The datum is, therefore, identified as station zero. An item located at station +50 would have an arm of 50 inches.

STATIONARY FRONT—A front that is moving at a speed of less than 5 knots.

STRATOSPHERE—A layer of the atmosphere above the tropopause extending to a height of approximately 160,000 feet.

STRESS MANAGEMENT—The personal analysis of the kinds of stress experienced while flying, the application of appropriate stress assessment tools, and other coping mechanisms.

SUBLIMATION—Process by which a solid is changed to a gas without going through the liquid state.

SUPERCHARGER—An engine- or exhaust-driven air compressor used to provide additional pressure to the induction air so the engine can produce additional power.

SUPERCOOLED WATER DROPLETS—Water droplets that have been cooled below the freezing point, but are still in a liquid state.

SURFACE ANALYSIS CHART—A report that depicts an analysis of the current surface weather. Shows the areas of high and low pressure, fronts, temperatures, dewpoints, wind directions and speeds, local weather, and visual obstructions.

TAKEOFF DISTANCE — The distance required to complete an all-engines operative takeoff to the 35-foot height. It must be at least 15 percent less than the distance required for a one-engine inoperative engine takeoff. This distance is not normally a limiting factor as it is usually less than the one-engine inoperative takeoff distance.

TAXIWAY LIGHTS—Omnidirectional lights that outline the edges of the taxiway and are blue in color.

TAXIWAY TURNOFF LIGHTS—Flush lights which emit a steady green color.

TELEPHONE INFORMATION BRIEFING SERVICE (TIBS)—Telephone recording of area and/or route meteorological briefings, airspace procedures, and special aviation-oriented announcements.

TERMINAL AERODROME FORECAST (TAF)—A report established for the 5 statute mile radius around an airport. Utilizes the same descriptors and abbreviations as the METAR report.

TERMINAL RADAR SERVICE AREAS (TRSA)—Areas where participating pilots can receive additional radar services. The purpose of the service is to provide separation between all IFR operations and participating VFR aircraft.

THERMOSPHERE—The last layer of the atmosphere that begins above the mesosphere and gradually fades away into space.

THRUST—The force which imparts a change in the velocity of a mass. This force is measured in pounds but has no element of time or rate. The term, thrust required, is generally associated with jet engines. A forward force which propels the airplane through the air.

THRUST LINE—An imaginary line passing through the center of the propeller hub, perpendicular to the plane of the propeller rotation.

TORQUE—**1.** A resistance to turning or twisting. **2.** Forces that produce a twisting or rotating motion. **3.** In an airplane, the tendency of the aircraft to turn (roll) in the opposite direction of rotation of the engine and propeller. **4.** In helicopters with a single, main rotor system, the tendency of the helicopter to turn in the opposite direction of the main rotor rotation.

TORQUEMETER—An instrument used with some of the larger reciprocating engines and turboprop or turboshaft engines to measure the reaction between the propeller reduction gears and the engine case.

TOTAL DRAG—The sum of the parasite and induced drag.

TOUCHDOWN ZONE LIGHTS—Two rows of transverse light bars disposed symmetrically about the runway centerline in the runway touchdown zone.

TRACK—The actual path made over the ground in flight.

TRAILING EDGE—The portion of the airfoil where the airflow over the upper surface rejoins the lower surface airflow.

TRANSCRIBED WEATHER BROADCAST (TWEB)—A continuous recording of weather and aeronautical information broadcast over selected NDB or VOR stations.

TRANSPONDER—The airborne portion of the secondary surveillance radar system.

TRICYCLE GEAR—Landing gear employing a third wheel located on the nose of the aircraft.

TRIM TAB—A small auxiliary hinged portion of a movable control surface that can be adjusted during flight to a position resulting in a balance of control forces.

TROPOPAUSE—The boundary layer between the troposphere and the mesosphere which acts as a lid to confine most of the water vapor, and the associated weather, to the troposphere.

TROPOSPHERE—The layer of the atmosphere extending from the surface to a height of 20,000 to 60,000 feet depending on latitude.

TRUE AIRSPEED (TAS)—Calibrated airspeed corrected for altitude and nonstandard temperature. Because air density decreases with an increase in altitude, an airplane has to be flown faster at higher altitudes to cause the same pressure difference between pitot impact pressure and static pressure. Therefore, for a given calibrated airspeed, true airspeed increases as altitude increases; or for a given true airspeed, calibrated airspeed decreases as altitude increases.

TRUE ALTITUDE—The vertical distance of the airplane above sea level—the actual altitude. It is often expressed as feet above mean sea level (MSL). Airport, terrain, and obstacle elevations on aeronautical charts are true altitudes.

TRUSS—A fuselage design made up of supporting structural members that resist deformation by applied loads. The truss-type fuselage is constructed of steel or aluminum tubing. Strength and rigidity is achieved by welding the tubing together into a series of triangular shapes, called trusses.

T-TAIL—An aircraft with the horizontal stabilizer mounted on the top of the vertical stabilizer, forming a T.

TURBINE DISCHARGE PRESSURE—The total pressure at the discharge of the low-pressure turbine in a dual-turbine axial-flow engine.

TURBINE ENGINE—An aircraft engine which consists of an air compressor, a combustion section, and a turbine. Thrust is produced by increasing the velocity of the air flowing through the engine.

TURBOCHARGER—An air compressor driven by exhaust gases, which increases the pressure of the air going into the engine through the carburetor or fuel injection system.

TURBOFAN ENGINE—A fanlike turbojet engine designed to create additional thrust by diverting a secondary airflow around the combustion chamber.

TURBOJET ENGINE—A turbine engine which produces its thrust entirely by accelerating the air through the engine.

TURBOPROP ENGINE—A turbine engine which drives a propeller through a reduction gearing arrangement. Most of the energy in the exhaust gases is converted into torque, rather than using its acceleration to drive the aircraft.

TURBOSHAFT ENGINE—A gas turbine engine that delivers power through a shaft to operate something other than a propeller.

TURN-AND-SLIP INDICATOR—A flight instrument consisting of a rate gyro to indicate the rate of yaw and a curved glass inclinometer to indicate the relationship between gravity and centrifugal force. The turn-and-slip indicator indicates the relationship between angle of bank and rate of yaw. Also called a turn-and-bank indicator.

TURN COORDINATOR—A rate gyro that senses both roll and yaw due to the gimbal being canted. Has largely replaced the turn-and-slip indicator in modern aircraft.

TURNING ERROR—One of the errors inherent in a magnetic compass caused by the dip compensating weight. It shows up only on turns to or from northerly headings in the Northern Hemisphere and southerly headings in the Southern Hemisphere. Turning error causes the compass to lead turns to the north or south and lag turns away from the north or south.

ULTIMATE LOAD FACTOR—In stress analysis, the load that causes physical breakdown in an aircraft or aircraft component during a strength test, or the load that according to computations, should cause such a breakdown.

UNCONTROLLED AIRPORT—An airport that does not have an operating control tower. Two-way radio communications are not required at uncontrolled airports, although it is good operating practice for pilots to transmit their intentions on the specified frequency.

UNCONTROLLED AIRSPACE—Class G airspace that has not been designated as Class A, B, C, D, or E. It is airspace in which air traffic control has no authority or responsibility to control air traffic; however, pilots should remember there are VFR minimums which apply to this airspace.

USEFUL LOAD—The weight of the pilot, copilot, passengers, baggage, usable fuel, and drainable oil. It is the basic empty weight subtracted from the maximum allowable gross weight. This term applies to general aviation aircraft only.

V_A—The design maneuvering speed. This is the "rough air" speed and the maximum speed for abrupt maneuvers. If during flight, rough air or severe turbulence is encountered, reduce the airspeed to maneuvering speed or less to minimize stress on the airplane structure. It is important to consider weight when referencing this speed. For example, V_A may be 100 knots when an airplane is heavily loaded, but only 90 knots when the load is light.

VAPOR LOCK—A condition in which air enters the fuel system and it may be difficult, or impossible, to restart the engine. Vapor lock may occur as a result of running a fuel tank completely dry, allowing air to enter the fuel system. On fuel-injected engines, the fuel may become so hot it vaporizes in the fuel line, not allowing fuel to reach the cylinders.

VARIATION—The angular difference between the true, or geographic, poles and the magnetic poles at a given point. The compass magnet is aligned with the magnetic poles, while aeronautical charts are oriented to the geographic poles. This variation must be taken into consideration when determining an aircraft's actual geographic location. Indicated on charts by isogonic lines, it is not affected by the airplane's heading.

VECTOR—A force vector is a graphic representation of a force and shows both the magnitude and direction of the force.

VELOCITY—The speed or rate of movement in a certain direction.

VERTICAL AXIS—An imaginary line passing vertically through the center of gravity of an aircraft. The vertical axis is called the z-axis or the yaw axis.

VERTICAL CARD COMPASS—A magnetic compass that consists of an azimuth on a vertical card, resembling a heading indicator with a fixed miniature airplane to accurately present the heading of the aircraft. The design uses eddy current damping to minimize lead and lag during turns.

VERTICAL SPEED INDICATOR—An instrument that uses static pressure to display a rate of climb or descent in feet per minute. The VSI can also sometimes be called a vertical velocity indicator (VVI).

VERTICAL STABILITY—Stability about an aircraft's vertical axis. Also called yawing or directional stability.

VERY HIGH FREQUENCY (VHF) OMNIDIRECTIONAL RANGE (VOR)—A ground-based electronic navigation aid transmitting very high frequency navigation signals, 360 degrees in azimuth, oriented from magnetic north. Used as the basis for navigation in the National Airspace System. The VOR periodically identifies itself by Morse Code and can have an additional voice identification feature. Voice features can be used by ATC or FSS for transmitting instructions/ information to pilots.

V_{FE}—The maximum speed with the flaps extended. The upper limit of the white arc.

VFR TERMINAL AREA CHARTS (1:250,000)—Depict Class B airspace which provides for the control or segregation of all the aircraft within the Class B airspace. The chart depicts topographic information and aeronautical information which includes visual and radio aids to navigation, airports, controlled airspace, restricted areas, obstructions, and related data.

V-G DIAGRAM—A chart that relates velocity to load factor. It is valid only for a specific weight, configuration and altitude and shows the maximum amount of positive or negative lift the airplane is capable of generating at a given speed. Also shows the safe load factor limits and the load factor that the aircraft can sustain at various speeds.

VISUAL APPROACH SLOPE INDICATOR (VASI)—The most common visual glidepath system in use. The VASI provides obstruction clearance within 10° of the extended runway centerline, and to 4 nautical miles (NM) from the runway threshold.

V_{LE}—Landing gear extended speed. The maximum speed at which an airplane can be safely flown with the landing gear extended.

V_{LO}—Landing gear operating speed. The maximum speed for extending or retracting the landing gear if using an airplane equipped with retractable landing gear.

V_{MC}—Minimum control airspeed. This is the minimum flight speed at which a light, twin-engine airplane can be satisfactorily controlled when an engine suddenly becomes inoperative and the remaining engine is at takeoff power.

V_{NE}—The never-exceed speed. Operating above this speed is prohibited since it may result in damage or structural failure. The red line on the airspeed indicator.

V_{NO}—The maximum structural cruising speed. Do not exceed this speed except in smooth air. The upper limit of the green arc.

VOR—See VERY HIGH FREQUENCY (VHF) OMNIDIRECTIONAL RANGE.

V_{S0}—The stalling speed or the minimum steady flight speed in the landing configuration. In small airplanes, this is the power-off stall speed at the maximum landing weight in the landing configuration (gear and flaps down). The lower limit of the white arc.

V_{S1}—The stalling speed or the minimum steady flight speed obtained in a specified configuration. For most airplanes, this is the power-off stall speed at the maximum takeoff weight in the clean configuration (gear up, if retractable, and flaps up). The lower limit of the green arc.

V-TAIL—A design which utilizes two slanted tail surfaces to perform the same functions as the surfaces of a conventional elevator and rudder configuration. The fixed surfaces act as both horizontal and vertical stabilizers.

V_X—Best angle-of-climb speed. The airspeed at which an airplane gains the greatest amount of altitude in a given distance. It is used during a short-field takeoff to clear an obstacle.

V_Y—Best rate-of-climb speed. This airspeed provides the most altitude gain in a given period of time.

V_{YSE}—Best rate of climb speed with one engine inoperative. This airspeed provides the most altitude gain in a given period of time in a light, twin-engine airplane following an engine failure.

WAKE TURBULENCE—Wingtip vortices that are created when an airplane generates lift. When an airplane generates lift, air spills over the wingtips from the high pressure areas below the wings to the low pressure areas above them. This flow causes rapidly rotating whirlpools of air called wingtip vortices or wake turbulence.

WARM FRONT— The boundary area formed when a warm air mass contacts and flows over a colder air mass. Warm fronts cause low ceilings and rain.

WARNING AREAS—Areas that may contain hazards to nonparticipating aircraft in international airspace. These areas are depicted on aeronautical charts.

WASTE GATE—A controllable valve in the tailpipe of an aircraft reciprocating engine equipped with a turbocharger. The valve is controlled to vary the amount of exhaust gases forced through the turbocharger turbine.

WEATHER DEPICTION CHART—Details surface conditions as derived from METAR and other surface observations.

WEIGHT—A measure of the heaviness of an object. The force by which a body is attracted toward the center of the Earth (or another celestial body) by gravity. Weight is equal to the mass of the body times the local value of gravitational acceleration. One of the four main forces acting on an aircraft. Equivalent to the actual weight of the aircraft. It acts downward through the aircraft's center of gravity toward the center of the Earth. Weight opposes lift.

WIND CORRECTION ANGLE—Correction applied to the course to establish a heading so that track will coincide with course.

WIND DIRECTION INDICATORS—Indicators that include a wind sock, wind tee, or tetrahedron. Visual reference will determine wind direction and runway in use.

WIND SHEAR—A sudden, drastic shift in windspeed, direction, or both that may occur in the horizontal or vertical plane.

WINDS AND TEMPERATURE ALOFT FORECAST (FD)—A twice daily forecast that provides wind and temperature forecasts for specific locations in the contiguous United States.

WING AREA—The total surface of the wing (square feet), which includes control surfaces and may include wing area covered by the fuselage (main body of the airplane), and engine nacelles.

WINGS—Airfoils attached to each side of the fuselage and are the main lifting surfaces that support the airplane in flight.

WING SPAN—The maximum distance from wingtip to wingtip.

WINGTIP VORTICES—The rapidly rotating air that spills over an airplane's wings during flight. The intensity of the turbulence depends on the airplane's weight, speed, and configuration. Also referred to as wake turbulence. Vortices from heavy aircraft may be extremely hazardous to small aircraft.

WING TWIST—A design feature incorporated into some wings to improve aileron control effectiveness at high angles of attack during an approach to a stall.

WORK—The product of force and the distance through which the force acts. Usually expressed in foot-pounds.

WORLD AERONAUTICAL CHARTS (WAC) (1:1,000,000)—Provide a standard series of aeronautical charts covering land areas of the world at a size and scale convenient for navigation by moderate speed aircraft. Topographic information includes cities and towns, principal roads, railroads, distinctive landmarks, drainage, and relief. Aeronautical information includes visual and radio aids to navigation, airports, airways, restricted areas, obstructions and other pertinent data.

ZULU TIME—A term used in aviation for coordinated universal time (UTC) which places the entire world on one time standard.

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